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Alaska Department of Fish and Game
Commercial Fisheries Management
and Development Division
P.O. Box 25526
Juneau, Alaska 99802-5526

June 1994

Bristol Bay Sockeye Salmon Smolt Studies For 1992

by

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and

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State of Alaska

Walter J. Hickel, Governor

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ABSTRACT

Numbers of sockeye salmon *Oncorhynchus nerka* smolt emigrating to sea from two rivers in Bristol Bay, Alaska, in 1992 were estimated from sonar counts and age-weight-length samples. Hydroacoustic equipment was used to estimate total smolt biomass, and age-weight-length samples were used to convert biomass estimates into numbers of smolt by age group. Estimated numbers of smolt emigrating were 79,490,008 from Kvichak River and 23,748,278 from Egegik River. Age-2. smolt, the progeny of 1989 spawners, predominated at both Kvichak River (77.1%) and Egegik River (73.0%).

KEY WORDS: smolt, sockeye salmon, *Oncorhynchus nerka*, smolt emigration, sonar, vertical distribution of passage, Bristol Bay, Kvichak River, Egegik River

INTRODUCTION

The Bristol Bay Management Area includes all waters east of a line from Cape Newenham to Cape Menshikof (Figure 1) and supports the largest sockeye salmon *Oncorhynchus nerka* fishery in the world. From 1983 to 1992 the commercial catch in Bristol Bay averaged 25.2 million sockeye salmon (ADF&G 1993). To effectively manage this fishery, managers need accurate abundance forecasts of returning adults and to determine optimum spawning escapement goals. Estimates of outmigrating smolt numbers are currently used as an index of production for adult salmon; this improves the accuracy of preseason forecasts and aids in setting goals for optimum numbers of spawners.

Fyke nets were used to estimate smolt numbers on Kvichak River from 1956 to 1970; on Naknek River from 1956 to 1978; on Egegik River during 1957, 1969, and 1978; on Ugashik River from 1955 to 1965, 1967 to 1970, and 1972 to 1975; and on Wood River from 1955 to 1966 (Burgner and Koo 1954; Rietze and Spangler 1958; Kerns 1961; Burgner 1962; Church 1963; Church and Nelson 1963; Jaenicke 1963, 1968; Nelson 1964, 1965a, 1965b, 1966a, 1966b, 1969; Nelson and Jaenicke 1965; Siedelman 1967, 1969; Shroeder 1972a, 1972b, 1974a; Pella and Jaenicke 1978). Although fyke net sampling provided information on age, size, and relative abundance of smolt, it did not provide an accurate estimate of total smolt numbers. To improve estimates of smolt numbers, the department began experimenting with and using hydroacoustic equipment.

Hydroacoustic equipment was used to estimate sockeye salmon smolt numbers on Kvichak River from 1971 through 1992; Wood River from 1975 to 1990; Naknek River from 1982 to 1986; Egegik River from 1982 through 1992; Ugashik River from 1983 to 1991; Nuyakuk River from 1983 to 1989; and Togiak River in 1988 (Russell 1972; Parker 1974a, 1974b; Krasnowski 1975; Randall 1976, 1977, 1978; Newcome 1978; Yuen 1980a, 1980b; Clark and Robertson 1980; Bucher 1980, 1981, 1982, 1983, 1984, 1986a, 1986b, 1987; Bergstrom and Yuen 1981; Yuen and Wise 1982; Eggers and Yuen 1984; Bue and Fried 1987; Bue 1986a, 1986b; Bue et al. 1988; Cross et al. 1990; Woolington et al. 1990; Woolington et al. 1991, Crawford et al.1992; Crawford and Cross 1992).

Hydroacoustic equipment developed by Bendix Corporation[1] was tested on Kvichak River in 1969 (McCurdy and Paulus 1972; Paulus and Parker 1974). Further testing and modification of this prototype resulted in the construction of smolt counters for use on Wood (Krasnowski 1976, 1977) and Kvichak Rivers (Randall 1977) in 1975 and 1976. Hydroacoustic equipment for counting smolt was tested on Ugashik River from 1973 to 1975 (Schroeder 1974b and 1975; Sanders 1976). Smolt studies on Naknek, Egegik, Ugashik, and Nuyakuk Rivers were limited to occasional fyke net sampling to obtain age and size data from 1975 to 1982 (Huttunen 1980; Eggers 1984; Minard 1984). An experimental two-array sonar system similar to the one used on Kvichak River was tested on Egegik River during 1981 (Bue 1982). Smolt enumeration projects using modified counters began on Naknek and Egegik Rivers in 1982 (Huttunen 1984; Bue 1984) and on Ugashik and Nuyakuk Rivers in 1983 (Fried et al. 1987; Minard and Frederickson 1987).

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[1] Use of a company's name does not constitute endorsement.

Side-scanning sonar was used in 1985 and 1986 to determine the lateral distribution of smolt passing each of the respective sonar sites. Bue et al. (1988) reported that most smolt passing the Kvichak River sonar site stayed within a 68-m corridor that was 6.4 m from the east bank (total river width = 100 m), that smolt passing the Egegik River sonar primarily used a 73-m corridor 12.2 m from the west bank (total river width = 104 m), and that Ugashik River smolt used a 21- m corridor which began 7.0 m from the south bank (total river width = 43 m). Side-scanning sonar was not an effective tool for collecting lateral smolt distribution data on the Wood River (Cross et al. 1990; Woolington et al. 1990, 1991). Therefore, lateral smolt distribution was assumed to be a function of river width and depth, measured and recorded when tidal influence was minimal. Based on those measurements, Wood River smolt were assumed to migrate within a 94-m corridor which began 3.3 m from the north bank.

Due to budget cuts, the monitoring of smolt migrations was discontinued on Naknek River in 1986 (Bue et al. 1988), on Togiak River in 1988 (Woolington et al. 1990), on Nuyakuk River in 1989 (Woolington et al. 1991), on Wood River in 1990 (Crawford et al. 1992), and on Ugashik River in 1992 (Crawford and Cross 1992).

In 1990 a single narrow-beam, side-looking sonar unit was used from May 29–31 to determine the lateral limits of smolt distribution at the Kvichak River sonar site (Huttunen and Skvorc 1991); most smolt migrated between 40 and 100 m offshore from the right bank. The total river width at the site was 136 m.

The results of the 1990 study were encouraging, so in 1991 it was expanded to evaluate the feasibility of using side-looking sonar to enumerate outmigrating Kvichak River sockeye salmon smolt. Huttunen and Skvorc (1992) estimated, based on 81 h of horizontal-aspect echo-integration data collected from June 2–14, that 44,972,864 smolt passed through the sonar site during the counting period. This compared well to an upward-looking sonar estimate of 43,525,980 smolt for the same hours of operation. The maximum single-beam listening range for the side-looking sonar varied from 118 m to 120 m, ensonifing 88%-90% of the total 134-m river cross section. In comparison, the three arrays of the historical upward-looking sonar ensonified roughly 7.5% of the river. The spacial distribution of smolt on a nightly basis were highly dynamic; side-looking estimates peaked at ranges from 64 m on June 12 to 118 m on June 7. Whereas the distribution of upward-looking estimates also varied between nights, the largest estimates were typically from the inshore array at 56 m from the right bank.

No side-looking sonar studies were done on Kvichak River in 1992 due to lack of funding. Upward-looking sonar studies were conducted on Kvichak and Egegik Rivers in 1992 to (1) estimate numbers of outmigrating sockeye salmon smolt; (2) describe smolt migration patterns; (3) collect smolt age, weight, and length data; and (4) record climatological and hydrological parameters which might affect migratory behavior.

METHODS

Hydroacoustic Equipment

Bendix Corporation constructed all hydroacoustic systems used to estimate smolt numbers in Bristol Bay river systems in 1992; a modified Model 1976 smolt counter was used at Kvichak River and a Model 1982 smolt counter was used at Egegik River. Transducers used to transmit and receive sound pulses at each sonar site were housed in three 3.03-m long arrays set on the river bottom and connected by coaxial cable to a control unit located on shore. Each Kvichak River array contained seven upward-facing single-element International Transducer Corporation (ITC), Model 5117 transducers which were designed to operate at a frequency of 118 kHz and a half power beamwidth angle of 18°. Each array at Egegik River housed ten upward-facing single-element ITC, Model 5095 transducers which were designed to operate at a frequency of 235 kHz and a half power beamwidth angle of 9°. Detected echos from each transducers were accumulated in the smolt counter and a printer produced a hard copy of totaled counts by array at prescribed intervals which were summed and recorded on a field data collection form hourly. Each smolt counting systems was powered by a single 12-volt battery recharged by a pair of 43 watt, 2.9 amp solar panels.

Hydroacoustic equipment to monitor smolt outmigrations was operated on Kvichak and Egegik Rivers from mid-May to mid-June. The smolt outmigrations in Kvichak and Egegik Rivers generally peak during late May or early June and drop off by mid-June. All arrays at each project site were removed from the water at the end of the field season.

Hydroacoustic systems were factory calibrated to record one count when a specified biomass passed through each transducer beam during a given period; these fish biomass units were 41.5 g for Egegik River and 83.0 g for Kvichak River. Because most smolt migrate within the upper portion of the water column, individual arrays were calibrated independently, which allowed the operator to set the counting range as near the surface as possible. The equipment was set to record counts to within 1–2 cm of the water surface to avoid counting debris or entrapped air.

Sources of false counts, e.g., boats, wind, rain, debris, were noted and the hydroacoustic equipment was disabled whenever false-count conditions were detected. Known false counts were subtracted from hourly totals, and linear interpolations were used to estimate counts missed while equipment was disabled. The control unit automatically recorded and stored the length of time the system was disabled. Manual control was available for adjusting printing intervals for accumulated counts, transducer pulse rate, and the portion of the water column monitored. Transducer signal characteristics were visually monitored with an oscilloscope. The Kvichak and Egegik River smolt counters each monitored three transducer arrays.

In 1989 the Kvichak River smolt counting system was relocated and modified so that one smolt counter on the right bank monitored three arrays and a second smolt counter on the left bank monitored a fourth array to account for the greater river width and depth at the new site. Analysis of the 1989 data (Woolington et al. 1991) revealed no advantages to using a three- versus four-array system; therefore, in 1990 only three arrays and one counter were used. The offshore transducer cables were also extended 100

ft to help enumerate smolt in the deep, fast water near the left bank. In addition, Al Menin of Bendix Corporation modified the Kvichak counter in 1989 and 1990 to enable counting in the deeper water at the new site. As a result of these changes, a new depth setting factor of 1.79 and a new formula, Water Depth = (Depth Setting)(1.79) + 3.0 ft, were introduced in 1990 to convert depth settings on the smolt counter to actual river depths. The additional 3.0 ft is an electronic blanking range that is built into the Kvichak River counter to account for the near-field effects. For a detailed discussion of near-field effects, refer to MacLennan and Simmonds (1992).

Project Locations

The 1992 Kvichak River counting site was located 6 km below the outlet of Lake Iliamna (Figure 1); it was moved to this location in 1989, approximately 1 km downstream from the site used during the previous 15 years (Woolington et al. 1991). The Kvichak River was 129 m wide at this site. Three transducer arrays referred to as *inshore, center,* and *offshore* (Figure 2), were anchored 49 m, 68 m, and 85 m from the right bank (the right bank is to the right when facing downstream). Array placement was improved by using lateral smolt distribution data reported by Huttunen and Skvorc (1991, 1992).

The Egegik River counting site was located 4 km below the outlet of Becharof Lake (Figure 1); it has been operated at this location since 1982 (Eggers and Yuen 1984). The Egegik River is 110 m wide at this site. The inshore, center, and offshore arrays were anchored 37 m, 55 m, and 67 m from the left bank (Figure 3).

Estimation of Smolt Numbers

The process of estimating smolt numbers was divided into three steps: (1) determining total fish biomass emigrating past the study site; (2) sampling the emigrating fish population to estimate species, age, weight, and length composition; and (3) converting fish biomass into numbers of smolt by age and species.

Biomass Estimation

Fish biomass was estimated using continually monitored hydroacoustic equipment. The signal pulse rate of the smolt counter was set to correspond with the river velocity measured over one array referred to as the *velocity index array.*

Estimation of River Velocities and Adjustments to Sonar Counts. River velocities at the Kvichak River site are nearly constant; thus velocities were measured once a week with a Gurley[3], Model 622 flow meter and the counter was adjusted accordingly.

River velocities at the Egegik River site are influenced by tides. Since 1986, Egegik River velocities have been measured continuously during the smolt project by a Marsh-McBirney[2] flow meter anchored directly behind the velocity index array, and the smolt counter was adjusted every 15–30 min to account for changes in river velocity. In 1992, the Marsh-McBirney flow meter was replaced with a Gurley[3], Model 622 flow meter at 2100 hours on 1 June because of widely varying and consistently low velocity readings from the Marsh-McBirney flow meter. From 1 June through the end of the project, river velocities were measured with the Gurley flow meter. Low velocity readings for the earlier period (24 May to 1 June) would result in the signal pulse rate of the smolt counter to be set too low, which would ultimately result in unrealistically low sonar counts. Therefore, a correction factor was developed by analyzing the relationship of depth to velocity from 2100 hours 1 June to 0830 hours 6 June (a period with a similar tide magnitudes as that prior to 1 June) and this relationship was applied back to the period from 1600 hours 24 May to 2030 hours 1 June.

Each 30-min data pair of depth velocity for smolt days from 1600 hours 24 May to 0830 hours 6 June was categorized into one of four tide stages (e.g., rising, high, falling, low). The paired data collected by the Gurley meter from 2100 hours 1 June to 0830 hours 6 June was graphically plotted and a least squares linear regression developed to model the relationship between river depth and velocity for each tide stage during this period:

$$\hat{V}_{mz} = \alpha_t + \beta_t d_{mz} + \varepsilon \quad , \tag{1}$$

where

$\hat{V}_{mz}$ = estimated velocity for time period m, day z,
d_{mz} = depth at period m, day z,
α_t,β_t = regression coefficients estimated by least square methods for tide stage model t, and
ε = random error with mean, 0, and variance s^2.

Significance level for each regression model was estimated with a F-test (Ho:$\beta = 0$, $P>0.25$; Snedecor and Cochran 1980). Velocity for each 30 min time segment for the period of incorrect velocity readings (1600 hours 24 May to 2030 hours 1 June) was then estimated using the linear regression models. A corrected factor was then calculated for each 30-min interval using the ratio of the original (Marsh-McBirney) water velocity reading to the corrected velocity estimate:

[2] Use of a company's name does not constitute endorsement.

$$\hat{CF}_{mz} = \frac{OV_{mz}}{\hat{V}_{mz}} \quad , \tag{2}$$

where

$\hat{CF}_{mz}$ = correction factor for smolt counts for 30-min period m, day z, and
OV_{mz} = original velocity reading for 30-min period m, day z.

Correction factors were calculated for each 30-min period, but sonar counts were totaled hourly. Therefore, correction factors estimated within the hour were averaged and multiplied by hourly sonar counts (e.g., estimated correction factors for 1200, 1230, and 1300 hours were averaged and multiplied by sonar counts accumulated between 1200 and 1300 hours).

To account for differences in river velocities between the index array and the remaining arrays (i), readings over each array were taken at specified intervals and velocity correction factors (vcf_i) were then calculated:

$$vcf_i = \frac{v_i}{v_{index}} \quad , \tag{3}$$

where

v_i = velocity over array i, and
v_{index} = velocity over the velocity index array.

Using these correction factors, adjustments to daily counts ($ac_{i,z}$) were made for differences in river velocity:

$$ac_{i,z} = c_{i,z}(vcf_i) \quad , \tag{4}$$

where $c_{i,z}$ = counts for array i on day z.

All sonar arrays monitored fish biomass 24 h/d, so daily counts for each array represented actual sonar counts. If an array was not monitored during an hour, counts were linearly interpolated using estimated counts from the previous and following hours.

Expansion of Biomass Estimates. The width of the section of river ($l_{i,z}$) monitored by array i on day z depended on array length (3.03 m), water depth over the array, and transducer signal beam width:

$$l_{i,z} = 3.03 + 2\left(d_{i,z} \tan\frac{bw}{2}\right) \quad , \tag{5}$$

where

$d_{i,z}$ = water depth over array i on day z, and
bw = transducer beam width in degrees .

Arrays were placed perpendicular to the river current; distances from each array to a reference point on one river bank were measured to the nearest foot. Estimates of the inshore and offshore limits of smolt passage were obtained with side-scanning hydroacoustic equipment. At sites where three arrays were used, distances were calculated between inshore limit of smolt passage to first array (D_1); first to second array (D_2); second to third array (D_3); and third array to offshore limit of smolt passage (D_4).

The biomass of fish ($\hat{B}_z$) passing the counting site on day z was estimated as follows:

$$\hat{B}_z = \frac{1}{2}D_1\left(\frac{ac_{1,z}}{l_{1,z}}\right) + \sum_{i=2}^{na}\left[\frac{1}{2}D_i\left(\frac{ac_{i-1,z}}{l_{i-1,z}} + \frac{ac_{i,z}}{1_{i,z}}\right) + \frac{1}{2}D_{na+1}\left(\frac{ac_{na,z}}{l_{na,z}}\right)\right] \quad , \tag{6}$$

where

D_i = the distance for interval i, and
na = number of transducer arrays used.

Age, Weight, and Length Estimation

Data on age, weight, and length of sockeye smolt were obtained from samples captured in a fyke net. Smolt weight in grams and length, from tip-of-snout to fork-of-tail, in millimeters were measured; age was determined from visual observations of scales mounted on glass slides. European ages -- i.e., 1., 2., or 3. depending on the number of freshwater annuli -- were used. Parent-year escapements that produced 1992 smolt occurred in 1990 for age-1. smolt, 1989 for age-2. smolt, and 1988 for age-3. smolt.

Sample size goals for Kvichak and Egegik Rivers were 400 smolt/d. Based on binomial proportions for the two major age groups, a sample size of 400 smolt would simultaneously estimate the percentage of each age class within 5% of the true percentage 95% of the time (Goodman 1965; Cochran 1977). When the daily goal of 400 smolt was not obtained, samples from subsequent days were combined until a total of at least 400 was reached.

Mean length of smolt differs among fyke net samples from a single day (Minard and Brandt 1986). Thus, to ensure that daily age composition estimates were representative of the population, attempts were made daily to obtain 100 smolt from each of six different fyke net catches. Because weight and age of smolt are strongly correlated to length, the time and cost of data collection was reduced by measuring all smolt collected each day: up to a maximum of 600 for length and weighing and sampling up to 100 of those smolt for age (Bue and Eggers 1989).

Weight was estimated for those smolt measured only for length using a least squares linear regression. Based on paired weight-length data obtained from smolt sampled for age, weight, and length, we estimated weights (W_j) of age j smolt measured only for length as explained by Ricker (1975):

$$W_j = \alpha L_j^{\beta} \quad , \tag{7}$$

where

L_j = fork length of an age j smolt, and

α and β = parameters which determine the y-axis intercept and the slope of the line.

Age was estimated for those smolt measured only for length using an age-length key (Bue and Eggers 1989). The key used length to categorize age-1. or -2. sockeye salmon smolt by determining a discriminant length that minimized classification error. This discriminant length was chosen such that the number of age-1. smolt classified as age-2. smolt was equal to the number of age-2. smolt classified as age-1. smolt.

Due to the variability of age and size composition estimates among subsamples (e.g., fyke net catches) taken the same day, daily mean weight ($\hat{W}$) and age proportions ($\hat{P}_j$) were estimated as the mean of subsampled values:

$$\hat{W} = \frac{\sum_{k=1}^{m} \left(\frac{\sum w_k}{n_k} \right)}{m} \quad , \tag{8}$$

where

m = number of subsamples collected during a sampling period,

w_k = observed weights from subsample k,

n_k = number of observations in subsample k, and

where $n_{j,k}$ = number of observations of age j in subsample k.

$$\hat{P}_j = \frac{\sum_{k=1}^{m}\left(\frac{n_{j,k}}{n_k}\right)}{m} \quad , \tag{9}$$

Estimation of Smolt Numbers

Numbers of smolt by age ($S\hat{P}C$) were estimated by combining biomass estimates with estimates of age and weight composition. Mean weight of smolt was used to convert estimates of biomass per count into estimates of smolt per count:

$$S\hat{P}C = \frac{BPC}{\hat{W}} \quad , \tag{10}$$

where BPC = biomass (g) per count.

The estimated number of smolt passing the counting site ($\hat{N}_z$) each day (z) was computed:

$$\hat{N}_z = \hat{B}_z(S\hat{P}C) \quad . \tag{11}$$

The estimated number ($\hat{N}_{j,z}$) of age j smolt on day z were then apportioned:

$$\hat{N}_{j,z} = \hat{N}_z(\hat{P}_j) \quad . \tag{12}$$

Finally, daily estimates of smolt numbers were summed: the season total of smolt passing the sonar site ($\hat{N}_{tot}$) was

$$\hat{N}_{tot} = \sum \hat{N}_z \tag{13}$$

and the estimated number of age j smolt that passed the site during the season ($\hat{N}_{jtot}$) was

$$\hat{N}_{jtot} = \sum \hat{N}_{j,z} \quad . \tag{14}$$

Vertical Distribution of Smolt Passage

Monitoring of vertical distribution of passing smolt schools was conducted with an oscilloscope during the 2 weeks of peak smolt passage. Vertical distribution of smolt was monitored for a total of approximately 1 h during each 8-h shift. Observers recorded the top and bottom depth (in centimeters) of passing smolt schools and spread their hour of monitoring throughout their shift and among all arrays. The arrays that received the highest counts were monitored most.

Climatological Data Collection

Climatological data were recorded at each counting site. Observations of sky conditions and measurements of wind direction, wind velocity (kilometers/hour), daily precipitation (millimeters), air and water temperatures (° Centigrade) were recorded at 0800 and 2000 hours daily.

RESULTS

Kvichak River

A total of 1,825,541 sonar counts were recorded at the Kvichak River counting site from May 23 to June 13, 1992 (Table 1). More counts were recorded over the offshore array (51.5%) than over the center (29.7%) or inshore (18.8%) arrays (Figure 4). Daily sonar counts were highest from May 25–29 when 73.6% of the total counts were recorded (Figures 5, 6). Over the course of the entire sampling season, about half of the total sonar counts were recorded from 2300 hours to 0300 hours (Figure 7); the other half was spread fairly evenly over the remaining hours. No direct observations or indicators (e.g., predator activity) of smolt migrating past the site prior to the start of the project were reported to or observed by the crew.

On May 19 the crew reported that the ice on Lake Iliamna was holding offshore. There was open water at the outlet of the lake in front of Igiugig, and there were no signs of ice or smolt in the Kvichak River. Sunny weather, a daytime high temperature of 14°C, and a slight easterly wind broke up some of Lake Iliamna's ice pack on May 20, and there was some ice flowing in the river by afternoon. The crew reported that there were large sections of open water visible on the lake; however, at least half of the lake remained ice covered. Easterly winds, which blew 24–32 km/hr during the night on May 21 pushed the remaining ice on Lake Iliamna down toward Igiugig and dumped large ice sheets into the river. On May 22 the ice flowed heavily in the Kvichak River all day. By the morning of May 23 the ice in the river cleared and the arrays were set in the river at the sonar site. The smolt counter was activated and counting began at 1400 hours on May 23. A fyke net fished in the Kvichak River from 2030 hours on May 23

until 0630 hours on May 24 caught the first sockeye salmon smolt (n=101) in 1992. Smolt counting was halted by ice in the river for 14.5 h on May 24, 8.5 h on May 25, 3.5 h on May 26, and 7.0 h on May 31. No ice was observed in the river after May 31.

Because of electrical problems, offshore array sonar counts were interpolated from 2400 hours May 23 to 2300 hours May 26. Sonar counts for all arrays were interpolated from 1600 to 2100 hours on May 31 because of a printer jam.

The peak daily sonar count of 465,218 occurred on May 28 but was probably too low. Between 2300 hours on May 28 and 0300 hours on May 29 smolt counting conditions were excellent and smolt passage was heavy. Large schools of smolt were observed above the smolt counting site in the main channel near the fyke net and in the back channel east of the fyke net. At the sonar site, smolt were observed within 10 m of the left bank, and the crew leader estimated that as many smolt passed outside the offshore array as over it.

River velocity measurements over the center index array , which were used to adjust the sonar counter firing rate, ranged from 1.1 m/s to 1.2 m/s. Velocity correction factors used for the three arrays were as follows:

	Inshore	Center	Offshore
May 23 – May 28	0.93	1.00	0.76
May 29 – June 6	0.95	1.00	0.79
June 7 – June 13	0.91	1.00	0.91

An estimated 79,490,008 sockeye salmon smolt migrated from the Kvichak River in 1992 (Table 2). Age-2. smolt (1989 brood year) composed 77.1% of the total migration. Although the daily percentage of age-1. and -2. smolt fluctuated during the 1992 migration, the percentage of age-1. smolts increased and the percentage of age-2. smolt decreased over time during project operations (NSC = nonstatistical comparison). Mean weight of smolt also generally decreased (NSC) during the season, which resulted in an increase in the estimated number of smolt per count (Table 3). Total production from the 1988 spawning escapement of 4,065,216 sockeye salmon was 19.88 smolt per spawner (Table 4). Marine survival (i.e., adult salmon returns per smolt) has averaged 11.2% for age-1. smolt for the 1969–1988 brood years and 14.6% for age-2. smolt for the 1968-1987 brood years (Table 5).

Age, weight, and length data were collected from 1,002 sockeye salmon smolt in 1992 (Table 6). All smolt sampled were age 1. or 2. Mean weight was 5.6 g for age-1. smolt and 9.3 g for age-2. smolt. Mean length was 84 mm for age-1. smolt and 100 mm for age-2. smolt. Age-1. and -2. smolt in 1992 were 5-7% shorter in length and 3-11% lighter in weight than the 1955–1991 average (Table 7). An additional 5,133 smolt were measured for length only (Table 8).

Fifty-two depth measurements were recorded for smolt schools passing over Kvichak River sonar arrays between May 25 and June 5 (Table 9). School passed from 18 to 108 cm below the surface. The water depth over the sonar arrays ranged from 269-300 cm. Data, although limited, suggest that depth of smolt passage may have varied diurnally (Figure 8). Depth ranges of 21–180 cm for smolt schools during

daylight (0500–2200 hours) tended to be farther from the surface than during darkness (2300–0400 hours) when depths were 0–122 cm.

River and weather conditions were recorded at the counting site from May 20 to June 14 (Table 10). Lake ice carried down the river halted smolt counting for 26.4 h on 6 occasions between May 24–26 and again for 7 h on May. The smolt counter was also disabled for 4 h on May 26 because of waves and entrained air from easterly winds gusting up to 32 km/h. Weather was generally good for smolt counting the rest of 1992. Mean water temperature during the project was 7.8° C (range 5.0–10.0°C), which was warmer (NSC) than the 1963–1991 mean of 5.6°C (Table 11). Mean daily water temperature during the peak of the smolt migration was 7.5°C on May 28.

Egegik River

Regression models of the relationships among river depths and velocities were significant at $\alpha = 0.05$ for the rising ($F = 60.5$ (2/54 d*f*), $P \approx 0$) and falling ($F = 81.7$ (2/121 d*f*), $P \approx 0$) tide stages (Figure 9). However, the relationships were not significant at $\alpha = 0.05$ among river depths and velocities for high ($F = 2.5$ (2/12 d*f*), $P \approx 0.124$) and low ($F = 0.14$ (2/21 d*f*), $P \approx 0.87$) tide stages (Figure 10). Therefore, we used the regression model on rising tides to estimate high tide velocities and the regression model on falling tides to estimate low tide velocities. Correction factors for sonar counts were calculated hourly and ranged from 1.00 to 2.01. The average of all hourly correction factors was 1.40.

A total of 1,799,290 adjusted sonar counts (unadjusted sonar count = 1,346,133) were recorded at the Egegik River counting site from May 22 to June 11, 1992 (Table 12). Most counts (45.9%) occurred over the center array (Figure 11). Daily sonar counts were highest during May 26–31 when 90.8% of the total counts were recorded (Figures 12 and 13). Over the course of the season, most sonar counts were recorded between 0300 hours and 0600 hours (Figure 14); 92% of all smolt counts were obtained between 2000 hours and 0800 hours.

No smolt or signs of smolt were observed prior to the start of the project. The sonar counter was installed and began counting at 1500 hours on May 22. The fyke net was fished for an hour or more each night from May 22 to 25 and no smolt were caught. The crew leader reported the first smolt counts on the sonar at 1905 hours on May 26. The first smolt catches in the fyke net were made between 2340 hours on May 26 and 0158 hours on May 27.

River velocity at the counting site ranged from 0.3 to 0.6 m/s over the sonar arrays. Historically, the inshore array has been used as the index array at this site. However, in 1992 water velocity over the inshore array was unusually slow (0.28 m/s), and few smolt were passing over this array. The water velocity at the center array was faster (0.52 m/s), and more smolt were passing over this array. Therefore, the center array was used as the index array starting on May 24, and the smolt counter was calibrated according to water velocities over the center array for the remainder of the 1992 field season. Velocity correction factors used for three arrays were as follows:

	Inshore	Center	Offshore
May 22 – May 23	1.00	1.70	1.83
May 24 – May 30	0.71	1.00	1.00
May 31 – June 8	0.81	1.00	1.02
June 9 – June 11	0.77	1.00	0.98

An estimated 23,748,278 sockeye salmon smolt (unadjusted estimate = 18,032,899) migrated from Egegik River in 1992 based on sonar counts (Table 13). Age-2. smolt composed 73.0% of the total migration. The daily percentage of age-2. smolt fluctuated between 93.3% and 37.3% during the migration. Mean weight of smolt decreased over the season (Table 14), resulting in an increased in the estimated number of smolt per count (NSC). Total production from the 1988 spawning escapement of 1,612,680 sockeye salmon was 57.87 smolt per spawner (Table 15). The 1992 smolt production from Egegik was slightly below average; mean production for brood years 1980–1988 was 58.31 smolt per spawner. The greatest smolt production was 106.84 smolt per spawner for the 1983 brood year. Average marine survival has been 24.1% for age-1. smolt for the 1980-1986 brood years and 28.6% for age-2. smolt for the 1979–1985 brood years (Table 16).

Age, weight, and length data were collected from 1,140 sockeye salmon smolt in 1992 (Table 17). Age-1., -2., and -3. smolt were sampled. Mean weights by age were 10.2 g age-1., 12.4 g age-2., and 17.6 g age-3. Mean length by age were 104 mm age-1., 112 mm age-2., and 127 mm age-3. In comparison to the 1939–1991 average, in 1992 age-1. smolt were average in length and 5% heavier, age-2. smolt were 4% shorter and 14% lighter, and age-3. smolt were 4% shorter and 17% lighter (Table 18). An additional 4,163 smolt were measured for length only (Table 19).

Sixty-one depth measurements were recorded for smolt schools passing over Egegik River sonar arrays between May 26 and June 11 (Table 20). Schools passed from 42 to 139 cm below the surface. Water depth over the sonar arrays at this site ranged from 274–335 cm. Data, although limited, suggest there was a diurnal effect upon the depth of smolt passage at Egegik River (Figure 15). However, this effect was less pronounced than at Kvichak, probably because of tidal influence. Once again, depth ranges of 40 to 240 cm for smolt schools during daylight (0500–2200 hours) tended to be farther from the surface than during darkness then during darkest (2300–0400 hours) when depths were 0–178 cm.

River and weather conditions were recorded at the counting site from May 21 to June 12 (Table 21). Becharof Lake and Egegik River were both reported to be ice-free by May 20; there were no problems with ice in 1992. Water levels 0.3 m lower than normal made boat transportation to and from the fyke net fishing site more difficult; however, it did not seem to affect smolt counts. The smolt counter was disabled for 1 h on June 4 because of waves and entrained air from easterly winds gusting at 40-72 km/h and 3 h on June 9 when the crew disabled the counter to conduct the weekly water velocity measurements over each array. Therefore, out of a total of 501 h of sonar operation in 1992, counts were adjusted by interpolation for only 4 h of disabled time. Mean water temperature during the season was 6.8°C (range 3.5–10.0°C), which was slightly higher (NSC) than the 1981–1991 average of 6.0°C (Table 22). Mean daily water temperature during the peak of the smolt outmigration on May 26 was 6.8°C.

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Table 1. Sonar counts recorded from three arrays at the sockeye salmon smolt counting site on Kvichak River, 1992.

Date [a]	Transducer Array			Total
	Inshore	Center	Offshore	
5/23 [b]	253	302	579	1,134
5/24 [b c]	9,763	4,256	14,935	28,954
5/25 [b c]	44,848	26,088	75,037	145,973
5/26 [b c d]	52,581	79,672	166,798	299,051
5/27	60,965	111,363	135,101	307,429
5/28 [e]	52,260	147,108	265,850	465,218
5/29	14,174	36,780	73,447	124,401
5/30	9,276	19,757	41,505	70,538
5/31 [c d]	13,329	14,599	25,569	53,497
6/01	3,465	5,265	5,086	13,816
6/02	2,826	1,667	4,310	8,803
6/03	66,956	78,768	89,276	235,000
6/04	10,650	12,296	14,658	37,604
6/05	534	616	3,785	4,935
6/06	1,040	1,469	16,474	18,983
6/07	108	189	97	394
6/08	82	189	94	365
6/09	14	31	102	147
6/10	74	83	55	212
6/11	263	106	179	548
6/12	345	643	2,733	3,721
6/13	265	486	4,067	4,818
Total	344,071	541,733	939,737	1,825,541
Percent	18.8	29.7	51.5	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] Offshore array data interpolated for the following hours and dates due to electronic problems:
2400 hours on May 23
0100-0500, 0700-1000, 2300-2400 hours on May 24
0100-0400, 0600, 0800, 1000-2400 hours on May 25
0100-2300 hours on May 26

[c] Smolt counting inhibited by ice for all or part of the hours indicated:
0600-2300 hours on May 24
0400-0800,1100-1300, 1400-1800, 2000-2100, 2300-2400 hours on May 25
0001-0300, 0400-0600 hours on May 26
0500-1300 hours on May 31

[d] Interpolated data for all arrays:
1100-1400 hours on May 26 due to wind
2230-2400 hours on May 26 due to repairs
1600-2100 hours on May 31 due to printer jam

[e] The crew leader reported the offshore array count on this date is probably low. Between 2300 hours May 28 and 0300 hours May 29 smolt counting conditions were excellent and smolt passage was heavy. Large schools of smolt were observed above the smolt counting site in the main channel by the fyke net and in the back channel east of the fyke net. At the sonar site, smolt were observed within 10 meters of the left bank and the crew leader estimated that as many smolt passed outside the offshore array as over it. At this rate the sonar count for this date could be 700,000 plus.

Table 2. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Kvichak River, 1992.

	Age 1.			Age 2.			All Ages	
Date [a]	Number	Percent	Cumulative Total	Number	Percent	Cumulative Total	Daily Total	Cumulative Total
5/23	2,286	5.5	2,286	39,583	94.5	39,583	41,869	41,869
5/24	62,069	5.5	64,355	1,074,730	94.5	1,114,313	1,136,799	1,178,668
5/25	180,073	3.2	244,428	5,394,953	96.8	6,509,266	5,575,026	6,753,694
5/26	342,272	3.2	586,700	10,254,389	96.8	16,763,655	10,596,661	17,350,355
5/27	408,518	3.5	995,218	11,296,884	96.5	28,060,539	11,705,402	29,0552757
5/28	3,260,882	17.3	4,256,100	15,577,262	82.7	43,637,801	18,838,144	47,893,901
5/29	2,936,857	47.0	7,192,957	3,317,098	53.0	46,954,899	6,253,955	54,147,856
5/30	1,270,356	37.1	8,463,313	2,151,940	62.9	49,106,839	3,422,296	57,570,152
5/31	1,682,219	52.8	10,145,532	1,505,009	47.2	50,611,848	3,187,228	60,757,380
6/01	302,779	39.4	10,448,311	466,281	60.6	51,078,129	769,060	61,526,440
6/02	199,072	39.4	10,647,383	306,572	60.6	51,384,701	506,644	62,032,084
6/03	5,244,446	39.4	15,891,829	8,076,474	60.6	59,461,175	13,320,920	75,353,004
6/04	1,132,597	50.4	17,024,426	1,150,066	49.6	60,576,241	2,247,663	77,600,667
6/05	165,070	59.4	17,189,496	112,638	40.6	60,688,879	277,708	77,878,375
6/06	608,553	59.4	17,798,049	415,258	40.6	61,104,137	1,023,811	78,902,186
6/07	15,162	59.4	17,813,211	10,346	40.6	61,114,483	25,508	78,927,694
6/08	13,994	63.9	17,827,205	7,895	36.1	61,122,378	21,889	78,949,583
6/09	5,378	63.9	17,832,583	3,034	36.1	61,125,412	8,412	78,957,995
6/10	8,591	63.9	17,841,174	4,847	36.1	61,130,259	13,438	78,971,433
6/11	23,580	63.9	17,864,754	13,304	36.1	61,143,563	36,884	79,008,317
6/12	135,208	63.9	17,999,962	76,285	36.1	61,219,848	211,493	79,219,810
6/13	172,738	63.9	18,172,700	97,460	36.1	61,317,308	270,198	79,490,008
	18,172,700	22.9		61,317,308	77.1		79,490,008	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 3. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Kvichak River, 1992.

Date [a]	Mean Weight of Smolt (g)	Smolt per Count
5/23	11.1	7.5
5/24	11.1	7.5
5/25	11.3	7.4
5/26	11.3	7.4
5/27	10.7	7.7
5/28	9.5	8.8
5/29	7.6	10.9
5/30	8.1	10.2
5/31	7.2	11.6
6/01	7.7	10.8
6/02	7.7	10.8
6/03	7.7	10.8
6/04	7.3	11.4
6/05	6.8	12.3
6/06	6.8	12.3
6/07	6.8	12.3
6/08	7.2	11.5
6/09	7.2	11.5
6/10	7.2	11.5
6/11	7.2	11.5
6/12	7.2	11.5
6/13	7.2	11.5

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 4. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production comprised by each age class, and number of smolt produced per spawner for 1956-1990 brood years, Kvichak River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced									
		Age 1.	(%[a])	Age 2.	(%[a])	Age 3.	(%[a])	Total	Per Spawner
		Estimates of smolt numbers based upon fyke net catches							
1956	9,443,318	3,267,274	(54)	2,777,960	(46)	0		6,045,234	0.64
1957	2,842,810	85,916	(13)	552,603	(87)	0		638,519	0.23
1958	534,785	61,400	(86)	10,126	(14)	0		71,526	0.13
1959	680,000	26,038	(27)	72,180	(73)	0		98,218	0.14
1960	14,630,000	1,130,820	(22)	4,116,093	(78)	0		5,246,913	0.36
1961	3,705,849	113,338	(7)	1,603,464	(93)	0		1,716,802	0.46
1962	2,580,884	458,122	(21)	1,748,178	(79)	0		2,206,300	0.86
1963	338,760	64,377	(73)	23,377	(27)	0		87,754	0.27
1964	957,120	252,384	(53)	222,528	(47)	0		474,912	0.50
1965	24,325,926	2,866,214	(34)	5,475,362	(66)	0		8,341,576	0.34
1966	3,775,184	648,321	(55)	541,017	(45)	0		1,189,338	0.32
1967	3,216,208	594,327	(67)	298,282	(33)	0		892,609	0.28
1968	2,557,440	185,356							
		Estimates of smolt numbers based upon sonar techniques							
1968				5,959,383		0		-	-
1969	8,394,204	85,723,430	(61)	54,159,340	(39)	0		139,882,770	16.66
1970	13,935,306	464,219	(<1)	191,842,930	(98)	2,918,768	(1)	195,225,917	14.01
1971	2,387,392	5,123,400	(19)	21,423,246	(81)	0		26,546,646	11.12
1972	1,009,962	2,740,610		-		-		-	-
1973	226,554	-		3,031,287		0		-	-
1974	4,433,844	108,356,892	(49)	114,269,848	(51)	0		222,626,740	50.21
1975	13,140,450	78,308,251	(27)	213,364,470	(73)	0		291,672,721	22.20
1976	1,965,282	32,226,544	(55)	26,423,348	(45)	0		58,649,892	29.84
1977	1,341,144	28,758,191	(73)	10,410,467	(27)	0		39,168,658	29.21
1978	4,149,288	182,442,540	(85)	32,294,536	(15)	0		214,737,076	51.75
1979	11,218,434	219,928,232	(71)	89,300,703	(29)	0		309,228,935	27.56
1980	17,505,268	150,421,026	(62)	76,244,773	(38)	0		199,172,858	12.95
1981	1,754,358	6,549,125	(15)	37,595,987	(85)	0		44,145,112	25.16
1982	1,134,840	51,893,988	(96)	1,937,408	(4)	2,065		53,833,461	47.44
1983	3,569,982	23,590,443	(31)	53,260,693	(69)	123,975		76,975,111	21.56
1984	10,490,670	83,470,460	(20)	331,384,545	(80)	43,135		414,898,140	39.55
1985	7,211,046	11,178,398	(11)	87,004,194	(89)	30,345		98,212,937	13.62
1986	1,179,322	13,126,363	(66)	6,830,717	(34)	0		19,957,080	16.92
1987	6,065,880	146,603,154	(78)	41,434,534	(22)	0		188,037,688	31.00
1988	4,065,216	46,569,569	(58)	34,266,421	(42)	0		80,835,990	19.88
1989	8,317,500	87,187,761	(59)	61,317,308	(41)			148,505,069	17.85
1990	6,970,020	18,172,700							

[a] Percent of total smolt production

[b] Preliminary total

Table 5. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1952-1990 brood years, Kvichak River.

Brood Year	Total Spawning Escapement	Age 1. Number of Smolt	Age 1. Adult[a] Returns	Age 1. Adult Returns per Smolt	Age 2. Number of Smolt	Age 2. Adult[a] Returns	Age 2. Adult Returns per Smolt
		Estimates of smolt numbers based upon fyke net catches					
1952	-	-			241,870	3,610,258	[b]
1953	-	18,198	152,165	[b]	47,373	424,627	[b]
1954	-	30,287	109,965	[b]	8,654	659,246	[b]
1955	-	22,253	351,240	[b]	66,679	1,132,813	[b]
1956	9,443,318	3,267,274	31,253,977	[b]	2,777,960	7,773,131	[b]
1957	2,842,810	85,916	488,844	[b]	552,603	3,591,552	[b]
1958	534,785	61,400	124,250	[b]	10,126	161,253	[b]
1959	680,000	26,038	328,287	[b]	72,180	217,593	[b]
1960	14,630,000	1,130,820	1,877,221	[b]	4,116,093	53,360,190	[b]
1961	3,705,849	113,338	524,416	[b]	1,603,464	2,971,816	[b]
1962	2,580,884	458,122	256,253	0.56	1,748,178	5,083,162	[b]
1963	338,760	64,377	98,571	[b]	23,377	1,008,242	[b]
1964	957,120	252,384	2,647,042	[b]	222,528	3,093,042	[b]
1965	24,325,926	2,866,214	10,349,415	[b]	5,475,362	34,671,692	[b]
1966	3,775,184	648,321	1,594,186	[b]	541,017	4,657,432	[b]
1967	3,216,208	594,327	621,690	[b]	298,282	900,307	[b]
1968	2,557,440	185,356	332,177	[b]	-		
		Estimates of smolt numbers based upon sonar techniques					
1968	2,557,440	-			5,959,383	209,138	0.04
1969	8,394,204	85,723,430	449,791	0.01	54,159,340	4,824,026	0.09
1970	13,935,306	464,219	56,778	0.12	191,842,930	15,351,498	0.08
1971	2,387,392	5,123,400	337,314	0.07	21,423,246	2,489,981	0.12
1972	1,009,962	2,740,610	436,837	0.16	-	1,504,435	[b]
1973	226,554	-	1,606,766	[b]	3,031,287	818,529	0.27
1974	4,433,844	108,356,892	8,353,542	0.08	114,269,848	17,796,617	0.16
1975	13,140,450	78,308,251	6,920,452	0.09	213,364,470	31,164,576	0.15
1976	1,965,282	32,226,544	6,132,390	0.19	26,423,348	4,431,284	0.17
1977	1,341,144	28,758,191	2,912,441	0.10	10,410,467	309,369	0.03
1978	4,149,288	182,442,540	2,991,655	0.02	32,294,536	2,151,024	0.07
1979	11,218,434	219,928,232	20,621,724	0.09	89,300,703	21,516,038	0.24
1980	22,505,268	150,421,026	4,534,253	0.03	76,244,773	8,508,770	0.11
1981	1,754,358	6,549,125	1,019,361	0.16	37,595,987	1,098,376	0.03
1982	1,134,840	51,893,988	995,144	0.02	1,937,408	663,241	0.34
1983	3,569,982	23,590,443	11,612,066	0.49	53,260,693	1,773,436	0.03
1984	10,490,670	83,470,460	4,455,429	0.05	331,384,545	19,441,947	0.06
1985	7,211,046	11,178,398	2,311,147	0.21	87,004,194	14,991,491	0.17
1986	1,179,322	13,126,363	1,804,257	0.14	6,830,717	2,721,114	0.40[c]
1987	6,065,880	146,603,154	6,705,780	0.05[c]	41,434,534	4,515,059	0.11[c]
1988	4,065,216	46,569,569	2,498,991	0.05[c]	34,266,421	18,741	0.00[c]
1989	8,317,500	87,187,761	1,760	0.00[c]	61,317,308		
1990	6,970,020	18,172,700					

[a] Includes estimates of returns through 1992.
[b] Insufficient smolt samples collected to perform this calculation.
[c] Future adult returns will increase these values.

Table 6. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Kvichak River, 1992.

	Age 1.					Age 2.				
Date [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/24	84	5.5	6.8	1.29	10	109	19.5	12.2	5.88	98
5/25					0	114	11.6	12.3	3.31	40
5/26					0	107	16.4	11.4	4.80	102
5/27	93	.0	7.3	.00	1	107	20.4	11.7	6.00	101
5/28	84	4.5	5.4	1.10	14	105	19.4	10.3	4.65	87
5/29	90	20.6	6.5	4.37	28	95	22.9	7.5	5.70	42
5/30	83	8.2	5.1	1.74	40	102	15.3	9.0	4.21	62
5/31	81	9.1	5.3	1.99	43	96	12.7	8.5	3.05	42
6/01	84	3.7	5.1	.94	7	102	13.1	9.9	4.00	27
6/02	83	4.6	5.0	.92	16	97	9.8	7.2	2.11	4
6/03	82	10.0	5.8	1.74	46	96	11.0	8.9	3.10	39
6/04	84	10.2	5.5	2.24	39	96	12.0	7.5	2.49	29
6/05	79	4.7	4.8	.74	8	93	4.4	7.3	1.36	9
6/06	81	7.0	5.2	1.22	17	96	8.8	8.3	1.86	17
6/07	79	12.2	4.5	2.42	20	93	6.5	7.0	1.92	14
Total					289					713
Mean	84		5.6			100		9.3		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 7. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Kvichak River, 1955-1992.

Year of Migration	Age 1. Percent of Total Estimate	Age 1. Mean Length (mm)	Age 1. Mean Weight (g)	Age 2. Percent of Total Estimate	Age 2. Mean Length (mm)	Age 2. Mean Weight (g)	Age 3. Percent of Total Estimate	Age 3. Mean Length (mm)	Age 3. Mean Weight (g)	Total Estimate	References
1955	7	89	-	93	-	-	0	-	-	260,068	Paulus and Parker (1974)
1956	39	92	-	61	116	-	0	-	-	77,660	"
1957	72	96	7.3	28	120	14.4	0	-	-	30,907	"
1958	98	84	4.6	2	114	-	0	-	-	3,333,953	"
1959	3	80	-	97	99	7.6	0	-	-	2,863,876	"
1960	10	91	6.3	90	108	10.3	0	-	-	614,003	"
1961	72	92	6.8	28	117	13.1	0	-	-	36,164	"
1962	94	82	4.3	6	110	9.9	0	-	-	1,203,000	"
1963	3	83	4.8	97	98	7.5	0	-	-	4,229,431	Marriott (1965)
1964	22	87	5.2	78	108	9.8	0	-	-	2,061,586	Pennoyer and Seibel (1965)
1965	4	90	6.8	96	109	11.3	0	-	-	1,812,555	Pennoyer (1966)
1966	92	94	7.4	8	114	12.6	0	-	-	275,761	Pennoyer and Stewart (1967)
1967	93	86	5.9	7	118	14.2	0	-	-	3,088,742	Pennoyer and Stewart (1969)
1968	11	88	5.5	89	104	9.2	0	-	-	6,123,683	Paulus and McCurdy (1969)
1969	52	92	5.7	48	109	10.6	0	-	-	1,135,344	McCurdy and Paulus (1972)
1970	38	91	6.0	62	110	11.0	0	-	-	483,638	Paulus and McCurdy (1972)
1971	93	90	5.8	7	111	11.1	0	-	-	91,682,813	Russell (1972)
1972	1	80	4.2	99	106	10.0	0	-	-	54,623,559	Parker (1974a)
1973	3	86	5.1	97	97	8.3	0	-	-	196,966,331	Parker (1974b)
1974	9	96	8.3	79	111	13.1	12	124	17.5	27,082,626	Krasnowski (1975)
1975	63	98	8.4	37	122	16.4	0	-	-	15,632,531	Randall (1976)
1976	97	88	5.8	3	121	14.2	0	-	-	111,388,180	Randall (1977)
1977	38	86	5.5	62	106	10.1	0	-	-	192,578,099	Randall (1978)
1978	12	88	6.0	88	97	7.8	0	-	-	245,591,014	Yuen (1980a)
1979	51	90	6.0	49	109	10.3	0	-	-	55,181,540	Yuen (1980b)
1980	94	88	5.9	6	110	10.7	0	-	-	192,853,007	Bergstrom and Yuen (1981)

-Continued-

Table 7. (p 2 of 2)

Year of Migration	Age 1. Percent of Total Estimate	Age 1. Mean Length (mm)	Age 1. Mean Weight (g)	Age 2. Percent of Total Estimate	Age 2. Mean Length (mm)	Age 2. Mean Weight (g)	Age 3. Percent of Total Estimate	Age 3. Mean Length (mm)	Age 3. Mean Weight (g)	Total Estimate [a]	References
1981	89	85	5.4	11	108	10.2	0	-	-	252,222,769	Yuen and Wise (1982)
1982	58	84	5.1	39	103	9.1	0	-	-	239,721,729	Bill (1984)
1983	8	80	4.9	92	98	8.5	0	-	-	82,793,899	Bill et al. (1987)
1984	58	90	6.8	42	104	10.0	0	-	-	89,489,975	Bill (1986a)
1985	92	85	5.3	8	102	9.2	0	-	-	25,527,851	Bill (1986b)
1986	61	84	5.5	39	107	10.4	0	102	9.1	136,733,218	Bue et al. (1988)
1987	3	82	4.5	97	96	7.0	0	97	8.5	342,686,918	Cross et al. (1990)
1988	13	86	5.6	87	99	8.3	0	107	9.8	100,173,692	Woolington et al. (1990)
1989	95	85	5.5	5	108	10.8	0	105	9.5	153,464,216	Woolington et al. (1991)
1990	53	87	6.1	47	105	10.5	0	-	-	88,004,103	Crawford et al. (1992)
1991	72	85	5.5	28	105	9.9	0	-	-	121,454,182	Crawford and Cross (1992)
Mean		88	5.8		108	10.5		107	10.9		
1992	23	84	5.6	77	100	9.3	0	_	_	79,490,008	

[a] Estimates of smolt numbers for 1955-1970 based on fyke net catches; estimates of smolt numbers for 1971-1992 based on hydroacoustic techniques.

Table 8. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Kvichak River, 1992.

	Estimated Age 1. [a]				Estimated Age 2. [a]			
Date [b]	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size
5/24	80	7.1	5.0	7	108	26.0	11.3	312
5/25				0	114	18.5	13.3	204
5/26	84	9.8	5.6	17	106	25.4	10.8	576
5/27	84	4.2	5.5	10	105	26.4	10.7	560
5/28	85	9.1	5.7	98	103	31.2	10.0	440
5/29	83	11.3	5.4	200	97	23.2	8.5	146
5/30	84	11.3	5.5	250	98	26.6	8.8	258
5/31	82	15.4	5.2	353	96	15.6	8.2	193
6/01				0	102	17.5	9.7	100
6/02	84	4.8	5.6	18	97	10.9	8.4	29
6/03	82	15.4	5.2	238	97	20.4	8.4	243
6/04	83	12.6	5.4	186	97	17.6	8.4	168
6/05	82	9.8	5.3	66	93	5.0	7.4	27
6/06	80	12.3	5.0	133	96	14.2	8.3	50
6/07	82	11.9	5.3	130	93	8.1	7.4	55
6/08	83	7.9	5.5	23	92	2.7	7.3	3
6/10	84	4.7	5.6	8				0
6/12	84	7.1	5.6	17	96	8.8	8.2	15
Total				1,754				3,379
Mean	83		5.4		99		9.1	

[a] Length-weight parameters by age group and discriminating length used to seperate ages from May 24 to June 7 were:

Age 1. a= -9.1634 b=2.4517 r^2=0.64 n=289
Age 2. a= -10.5618 b=2.7712 r^2=0.85 n=713

Discriminating Length = 89.97 mm

[b] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 9. Depth of sockeye salmon smolt passage at Kvichak River sonar site, May 25 to June 5, 1992.

	Depth of Passage (cm)							
	Inshore Array[a] Smolt Schools		Center Array[b] Smolt Schools		Offshore Array[c] Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mean	23	117	19	108	13	99	18	108
Minimum	0	59	0	45	0	68	0	45
Maximum	100	180	85	160	77	150	100	180
n	16	16	19	19	17	17	52	52

[a] Total depth at inshore array is 300 cm.
[b] Total depth at center array is 274 cm.
[c] Total depth at offshore array is 269 cm.

Table 10. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Kvichak River, 1992.

Date	Cloud Cover [a]		Wind Velocity (km/h)		Air Temp (°C)		Water Temp (°C)		Percipitation (mm)	Water Clarity [b]
	0800	2000	0800	2000	0800	2000	0800	2000		
5/20	1	1	-	-	-	-	-	-	-	clear
5/21	1	1	0-08 var	0-08 var	-	-	-	-	0.0	clear
5/22	1	1	variable	8-16 SW	-	-	6.5	-	0.0	clear
5/23	1	1	0-08 SW	0-08 E	-	19.0	6.0	6.5	0.0	clear
5/24	1	1	08 E	0-08 E	-	21.0	5.0	7.0	0.0	clear
5/25	2	4	0-08 NW	calm	12.0	17.0	5.0	6.0	0.0	clear
5/26	2	3	08 NE	16-24 E	10.0	15.0	6.0	8.0	0.0	clear
5/27	4	3	16 E	16 E	11.0	15.0	7.5	8.0	0.0	clear
5/28	2	3	8-24 E	8-16 E	10.0	16.0	7.0	8.0	trace	clear
5/29	3	3	8-16 E	8-16 E	13.0	16.0	7.0	8.0	0.0	clear
5/30	2	3	5-08 E	calm	10.0	16.5	6.5	6.7	0.0	clear
5/31	1/5	3	calm	calm	8.0	13.0	5.5	6.0	3.8	clear
6/01	4	-	16 S	0-11 SW	9.0	14.0	6.0	7.0	0.0	clear
6/02	4	3	calm	16-32 E	14.0	14.5	6.0	8.0	trace	clear
6/03	4	4	16-24 E	24 NE	14.0	14.0	7.0	8.0	0.0	murky
6/04	4	3	8-16 E	24 E	13.5	16.0	7.5	8.5	0.0	lt brown
6/05	4	3	16-24 E	8-24 E	11.0	14.0	8.0	9.0	0.0	brown
6/06	3	-	3-08 E	calm	9.0	14.0	8.0	9.5	0.0	brown
6/07	3	3	8-13 SW	16-32 SW	9.5	18.0	8.5	9.5	0.0	clear
6/08	3	2	16-24 SW	16-24 SW	9.0	18.0	8.5	9.5	0.0	lt brown
6/09	2	3	16-24 SW	8-16 SW	9.0	18.0	9.0	10.0	0.0	lt brown
6/10	3	4	0-08 SW	8-16 W	11.5	15.0	9.0	9.5	0.0	clear
6/11	4	4	0-08 E	8-16 W	15.0	14.0	9.0	9.5	4.3	lt brown
6/12	4	4	8-16 E	8-24 E	13.5	16.0	9.0	9.5	3.8	lt brown
6/13	4	4	8-16 E	calm	14.0	13.0	9.0	9.5	2.3	murky
6/14	4/5	-	0-08 E	-	12.0	-	9.0	-	-	brown

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] Water clarity at 0800 hours

Table 11. Water temperatures at sockeye salmon smolt counting site, Kvichak River, 1963-1992.

Year	Sample Period	Water Temperature (°C) Minimum	Maximum	Mean	References
1963	May 16 - Jun 14	2.2	8.9	5.5	Marriott (1965)
1964	May 18 - Jun 14	0.0	5.6	2.6	Pennoyer and Seibel (1965)
1965	May 17 - Jun 11	0.0	8.9	4.4	Pennoyer (1966)
1966	May 16 - Jun 26	0.0	11.1	4.7	Pennoyer and Stewart (1967)
1967	May 17 - Jun 20	1.1	9.4	6.9	Pennoyer and Stewart (1969)
1968	May 12 - Jun 12	3.3	8.3	5.4	Paulus and McCurdy (1969)
1969	May 16 - Jun 18	0.3	7.8	3.9	McCurdy and Paulus (1972)
1970	May 13 - Jun 07	2.8	11.1	6.8	Paulus and McCurdy (1972)
1971	May 17 - Jun 20	1.1	3.3	2.4	Russell (1972)
1972	May 18 - Jun 18	0.6	5.0	2.9	Parker (1974a)
1973	May 15 - Jun 14	2.9	8.9	4.9	Parker (1974b)
1974	May 13 - Jun 09	3.0	8.0	6.2	Krasnowski (1975)
1975	May 17 - Jun 15	2.0	8.0	3.8	Randall (1976)
1976	May 18 - Jun 19	2.0	9.5	3.9	Randall (1977)
1977	May 17 - Jun 14	3.0	9.5	6.4	Randall (1978)
1978	May 19 - Jun 09	5.0	11.0	7.6	Yuen (1980a)
1979	June 1 - Jun 10	8.0	10.0	8.6	Yuen (1980b)
1980	May 16 - Jun 18	1.5	9.0	5.5	Bergstrom and Yuen (1981)
1981	May 15 - Jun 09	7.0	10.0	8.2	Yuen and Wise (1982)
1982	May 14 - Jun 15	2.5	8.5	4.9	Bill (1984)
1983	May 19 - Jun 14	5.2	10.5	7.9	Bill et al. (1987)
1984	May 19 - Jun 11	5.5	10.0	7.9	Bill (1986a)
1985	May 23 - Jun 20	2.0	7.0	4.6	Bill (1986b)
1986	May 18 - Jun 12	1.0	7.0	4.6	Bue et al. (1988)
1987	May 21 - Jun 13	4.5	9.0	6.7	Cross et al. (1990)
1988	May 17 - Jun 17	3.0	11.0	7.1	Woolington et al. (1990)
1989	May 19 - Jun 16	3.0	8.8	5.8	Woolington et al. (1991)
1990	May 22 - Jun 15	3.5	9.5	7.3	Crawford et al. (1992)
1991	May 23 - Jun 17	1.0	8.5	4.8	Crawford and Cross (1992)
	Mean	2.7	8.7	5.6	
1992	May 22 - Jun 14	5.0	10.0	7.8	

Table 12. Sonar counts recorded from three arrays at the sockeye salmon smolt counting site on Egegik River, 1992.

Date [a]	Sonar Counts: Transducer Array: Inshore	Center	Offshore	Total
5/22	0	4	12	16
5/23	0	27	0	27
5/24 [b]	269	156	465	890
5/25 [b]	287	59	260	606
5/26 [b]	280,880	323,933	112,617	717,430
5/27 [b]	55,688	145,871	61,986	263,545
5/28 [b]	80,226	94,764	17,802	192,792
5/29 [b]	82,448	34,939	8,780	126,167
5/30 [b]	74,293	54,863	3,889	133,045
5/31 [b]	63,034	87,008	50,489	200,531
6/01 [b]	3,005	15,448	160	18,613
6/02	4,518	8,960	1,499	14,977
6/03 [c]	8,344	10,876	2,864	22,084
6/04	2,310	3,067	844	6,221
6/05	20,427	22,604	846	43,877
6/06	4,085	3,483	140	7,708
6/07	4,395	6,853	10,068	21,316
6/08	622	1,673	2,350	4,645
6/09 [c]	1,392	1,186	479	3,057
6/10	672	1,731	285	2,688
6/11	8,439	8,392	2,224	19,055
Total	695,334	825,897	278,059	1,799,290
Percent	38.6	45.9	15.5	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

[b] All sonar counts from 1600 hours May 24 to 2030 hours June 1 were multiplied by a correction factor (average = 1.41) to to correct for low water velocity measurements.

[c] Data interpolated for one or more arrays on the following hours and dates: 0100 hours on June 4
1700-1900 hours on June 9

Table 13. Daily number of sockeye salmon smolt emigrating seaward estimated with hydroacoustic equipment, Egegik River, 1992.

Date [a]	Age 1. Number	Age 1. Percent	Age 1. Cumulative Total	Age 2. Number	Age 2. Percent	Age 2. Cumulative Total	Age 3. Number	Age 3. Percent	Age 3. Cumulative Total	All Ages Daily Total	All Ages Cumulative Total
5/22	10	3.8	10	253	93.3	253	7	2.9	7	270	270
5/23	18	3.8	28	450	93.3	703	13	2.9	20	481	751
5/24	387	3.8	415	9,483	93.3	10,186	292	2.9	312	10,162	10,913
5/25	264	3.8	679	6,488	93.3	16,674	200	2.9	512	6,952	17,865
5/26	302,342	3.8	303,021	7,404,609	93.3	7,421,283	228,542	2.9	229,054	7,935,493	7,953,358
5/27	1,108,674	30.1	1,411,695	2,547,923	69.1	9,969,206	32,835	0.9	261,889	3,689,432	11,642,790
5/28	742,514	27.5	2,154,209	1,937,135	71.6	11,906,341	24,335	0.9	286,224	2,703,984	14,346,774
5/29	687,097	36.4	2,841,306	1,188,161	62.9	13,094,502	13,598	0.7	299,822	1,888,856	16,235,630
5/30	743,919	38.5	3,585,225	1,179,757	61.0	14,274,259	9,083	0.5	308,905	1,932,759	18,168,389
5/31	1,032,779	34.5	4,618,004	1,935,562	64.6	16,209,821	26,957	0.9	335,862	2,995,298	21,163,687
6/01	98,650	38.2	4,716,654	155,070	60.1	16,364,891	4,230	1.6	340,092	257,950	21,421,637
6/02	82,754	38.2	4,799,408	130,083	60.1	16,494,974	3,549	1.6	343,641	216,386	21,638,023
6/03	123,893	38.2	4,923,301	194,750	60.1	16,689,724	5,313	1.6	348,954	323,956	21,961,979
6/04	65,780	64.0	4,989,081	36,229	35.3	16,725,953	739	0.7	349,693	102,748	22,064,727
6/05	420,035	64.0	5,441,116	248,965	35.3	16,974,918	5,083	0.7	354,776	706,083	22,770,810
6/06	79,131	64.0	5,520,247	43,583	35.3	17,018,501	889	0.7	355,665	123,603	22,894,413
6/07	230,392	61.9	5,750,639	139,725	37.5	17,158,226	2,384	0.6	358,049	372,501	23,266,914
6/08	50,152	61.9	5,800,791	30,415	37.5	17,188,641	518	0.6	358,567	81,085	23,347,999
6/09	30,471	61.9	5,831,262	18,480	37.5	17,207,121	315	0.6	358,882	49,266	23,397,265
6/10	26,510	61.9	5,857,772	16,077	37.5	17,223,198	274	0.6	359,156	42,861	23,440,126
6/11	190,592	61.9	6,048,364	115,588	37.5	17,338,786	1,972	0.6	361,128	308,152	23,748,278
	6,048,364	25.5		17,338,786	73.0		361,128	1.5		23,748,278	

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 14. Adjustment factors used to expand sonar counts into estimated numbers of sockeye salmon smolt, Egegik River, 1992.

Date [a]	Mean Weight of Smolt (g)	Smolt per Count
5/22	15.8	2.6
5/23	15.8	2.6
5/24	15.8	2.6
5/25	15.8	2.6
5/26	15.8	2.6
5/27	12.4	3.3
5/28	12.4	3.4
5/29	11.8	3.5
5/30	12.0	3.5
5/31	12.2	3.4
6/01	12.2	3.4
6/02	12.2	3.4
6/03	12.2	3.4
6/04	10.8	3.8
6/05	10.8	3.8
6/06	10.8	3.8
6/07	10.8	3.9
6/08	10.8	3.9
6/09	10.8	3.9
6/10	10.8	3.9
6/11	10.8	3.9

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 15. Sockeye salmon spawning escapement, total number of smolt produced by age class, percent of total smolt production composed by each age class, and number of smolt produced per spawner for 1978-1990 brood years, Egegik River.

Brood Year	Total Spawning Escapement	Number of Smolt Produced				
		Age 1. (%)[a]	Age 2. (%)[a]	Age 3.	Total	Per Spawner
1978	895,698	-	-	225,522	-	-
1979	1,032,042	-	14,287,075	0	-	-
1980	1,060,860	49,457,563 (75)	16,524,563 (25)	197,429	66,179,555	62.38
1981	694,680	2,242,326 (7)	32,235,734 (93)	52,852	34,530,912	49.71
1982	1,034,628	17,234,269 (60)	11,434,848 (40)	564	28,669,681	27.71
1983	792,282	54,585,828 (65)	29,984,140 (35)	85,087	84,655,055	106.84
1984	1,165,320	14,016,441 (24)	45,386,536 (76)	80,931	59,483,908	51.05
1985	1,095,204	4,397,087 (26)	12,758,135 (74)	81,150	17,236,372	15.74
1986	1,151,320	36,122,149 (57)	27,347,612 (43)	0	63,469,761	55.13
1987	1,272,978	72,458,024 (58)	52,299,487 (42)	396,423	125,153,934	98.32
1988	1,612,680	3,795,739 (4)	89,162,038 (96)	361,128	93,318,905	57.87
1989	1,610,916	4,519,527 (21)	17,338,786 (79)		21,858,313[b]	13.57[b]
1990	2,191,362	6,048,364				

[a] Percent of total smolt production

[b] Preliminary total

Table 16. Sockeye salmon spawning escapements, smolt production, adult returns, and smolt survival (number of adults produced per smolt) for 1978-1990 brood years, Egegik River.

Brood Year	Total Spawning Escapement	Age 1. Number of Smolt	Age 1. Adult[a] Returns	Age 1. Adult Returns per Smolt	Age 2. Number of Smolt	Age 2. Adult[a] Returns	Age 2. Adult Returns per Smolt	Age 3. Number of Smolt	Age 3. Adult[a] Returns	Age 3. Adult Returns per Smolt
1978	895,698	-	908,379		-	8,264,740		225,522	33,395	0.15
1979	1,032,042	-	1,239,273		14,287,075	4,705,018	0.33	0	0	0.00
1980	1,060,860	49,457,563	3,035,494	0.06	16,524,563	5,519,025	0.33	197,429	7,730	0.04
1981	694,680	2,242,326	1,508,516	0.67	32,235,734	4,785,803	0.15	52,852	16,119	0.30
1982	1,034,628	17,234,269	2,873,325	0.17	11,434,848	3,447,534	0.30	564	12,739	[b]
1983	792,282	54,585,828	4,520,747	0.08	29,984,140	6,085,720	0.20	85,087	37,329	0.44
1984	1,165,320	14,016,441	1,596,859	0.11	45,386,536	11,482,531	0.25	80,931	249,131	[b]
1985	1,095,192	4,397,087	1,951,334	0.44	12,758,135	5,558,244	0.44	81,150	26,295	0.32[c]
1986	1,151,320	36,122,149	5,664,220	0.16	27,347,612	8,468,439	0.31[c]	0	87,315	[b]
1987	1,272,978	72,458,024	5,453,429	0.08[c]	52,299,487	8,946,524	0.17[c]	396,423	3,093	0.01[c]
1988	1,612,680	3,795,739	414,337	0.11[c]	89,162,038	62,330	0.00[c]	361,128		
1989	1,610,916	4,519,527	0	0.00[c]	17,338,786					
1990	2,191,362	6,048,364								

[a] Includes estimates of returns through 1992.

[b] Insufficient Age 3. smolt sampled to perform this calculation.

[c] Future adult returns will increase these values.

Table 17. Mean fork length and weight of sockeye salmon smolt captured in fyke nets, Egegik River, 1992.

	Age 1.					Age 2.					Age 3.				
Date [a]	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size	Mean Length (mm)	Std. Error	Mean Weight (g)	Std. Error	Sample Size
5/26	104	6.1	11.3	2.37	7	120	29.5	15.9	10.31	73	131	10.5	21.6	3.07	18
5/27	106	16.9	9.7	4.10	36	112	16.2	12.3	5.85	61	132	9.8	19.4	3.39	3
5/28	108	7.2	10.4	3.22	20	116	17.6	13.0	6.66	77	127	10.4	16.2	4.52	3
5/29	102	13.5	9.6	3.42	47	111	15.8	11.1	4.66	51	118		14.4		1
5/30	105	15.0	11.1	4.46	54	110	18.4	12.6	5.61	46					0
5/31	107	16.0	11.5	5.05	25	114	23.9	13.0	7.87	71	126	12.8	16.1	2.97	3
6/02	104	12.7	10.2	3.39	45	115	20.8	13.3	7.27	51	130	2.1	18.7	0.61	4
6/03	103	12.3	9.9	3.62	64	113	19.4	12.6	5.75	33	130		17.7		1
6/06	100	11.1	9.4	3.67	70	111	18.9	12.0	6.25	26	120		14.4		1
6/07	103	7.5	9.7	2.34	20	109	7.9	11.5	2.37	9					0
6/08	104	9.9	9.7	3.07	40	111	18.7	11.9	5.69	47	132	2.5	19.4	2.06	3
6/10	105	11.8	9.9	2.78	22	114	13.8	12.2	4.71	11					0
6/11	102	16.6	9.9	4.66	74	102	15.9	9.6	4.09	23					0
Total					524					579					37
Mean	104		10.2			112		12.4			127		17.6		

[a] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 18. Age composition of total migration and mean fork length and weight by age class for sockeye salmon smolt, Egegik River, 1939-1992.

Year of Migration	Age 1. Percent of Total Estimate	Age 1. Mean Length (mm)	Age 1. Mean Weight (g)	Age 2. Percent of Total Estimate	Age 2. Mean Length (mm)	Age 2. Mean Weight (g)	Age 3. Percent of Total Estimate	Age 3. Mean Length (mm)	Age 3. Mean Weight (g)	Total Estimate [a]	References
1939	-	96	-	-	105	-	-	-	-	-	USF&WS (unpublished)
1956	-	101	-	-	116	-	-	123	-	-	"
1957	-	107	-	-	120	-	-	130	-	-	"
1959	-	99	-	-	116	-	-	123	-	-	"
1960	-	106	-	-	115	-	-	140	-	-	"
1969	-	99	-	-	119	-	-	115	-	-	Paulus (1972)
1977	-	110	11.3	-	116	13.3	-	-	-	-	ADF&G (unpublished)
1978	-	104	10.1	-	122	15.4	-	130	18.1	-	Huttunen (1980)
1981	-	105	9.1	-	122	16.6	-	128	19.1	-	Bue (1982)
1982	77	104	9.2	23	130	17.1	0	145	23.5	63,970,160	Bue (1984)
1983	12	101	9.3	88	116	13.6	0	-	-	18,766,889	Fried et al. (1987)
1984	35	106	10.1	65	112	12.2	0	134	20.2	49,667,432	Fried et al. (1986)
1985	83	106	10.4	17	123	16.8	0	138	24.1	66,073,548	Bue (1986c)
1986	32	101	9.0	68	122	15.7	0	140	22.6	44,197,865	Bue et al. (1988)
1987	9	107	11.6	91	114	14.1	0	128	18.9	49,868,710	Cross et al. (1990)
1988	74	103	10.2	26	117	14.3	0	136	21.2	48,961,215	Woolington et al. (1990)
1989	73	99	8.9	27	119	15.4	0	135	21.1	99,886,786	Woolington et al. (1991)
1990	7	102	9.6	93	118	14.5	0	-	-	56,095,226	Crawford et al. (1992)
1991	5	102	10.3	95	118	15.6	0	140	24.4	94,095,226	Crawford and Cross (1992)
Mean		102	9.7		117	14.7		132	21.3		
1992	26	104	10.2	73	112	12.4	1	127	17.6	23,748,278	

[a] No estimates of smolt numbers from 1939-1981 fyke net catches; estimates of smolt numbers for 1982-1992 based on hydroacoustic techniques.

Table 19. Mean fork length and estimated mean weight for age-1. and -2. sockeye salmon smolt, Egegik River, 1992.

	Estimated Age 1. [a]				Estimated Age 2. [a]			
Date [b]	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size	Mean Length (mm)	Std. Error	Estimated Weight (g)	Sample Size
5/26	104	4.8	10.1	20	123	35.8	15.7	502
5/27	102	13.5	9.7	188	116	30.8	13.6	406
5/28	103	10.5	9.8	155	115	27.3	13.2	351
5/29	103	10.2	9.9	152	114	19.9	12.8	250
5/30	102	11.6	9.7	211	114	23.2	13.0	318
5/31	103	11.3	9.8	207	115	28.7	13.2	318
6/02	103	7.2	9.9	26	116	23.2	13.5	74
6/03	103	7.2	9.8	44	113	17.3	12.8	73
6/06	101	14.0	9.5	304	113	22.5	12.7	113
6/08	101	8.0	9.5	60	113	17.0	12.8	43
6/11	101	12.2	9.4	240	113	21.4	12.6	108
Totals				1,607				2,556
Means	102		9.7		115		13.3	

[a] Length-weight parameters by age group and discriminating length used to seperate ages from May 26 to June 11 were:

Age 1. $a = -8.3718$ $b = 2.2973$ $r^2 = 0.62$ $n = 524$
Age 2. $a = -9.5857$ $b = 2.5606$ $r^2 = 0.66$ $n = 579$

Discriminating Length = 107.57 mm

[b] Sample day began at 1200 hours and ended at 1159 hours the next calendar day.

Table 20. Depth of sockeye salmon smolt passage at Egegik River sonar site, May 26 to June 11, 1992.

	Depth of Passage (cm)							
	Inshore Array[a] Smolt Schools		Center Array[b] Smolt Schools		Offshore Array[c] Smolt Schools		All Combined Smolt Schools	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Mean	30	111	44	136	42	145	42	139
Minimum	0	60	0	60	0	50	0	50
Maximum	80	160	120	240	120	230	120	240
n	6	6	21	21	34	34	61	61

[a] Total depth at inshore array is 335 cm.
[b] Total depth at center array is 335 cm.
[c] Total depth at offshore array is 274 cm.

Table 21. Climatological and hydrological observations made at sockeye salmon smolt counting site at 0800 and 2000 hours, Egegik River, 1992.

Date	Cloud Cover[a]		Wind Velocity (km/h)		Air Temp. (°C)		Water Temp. (°C)		Precipitation (mm)	Water Clarity[b]
	0800	2000	0800	2000	0800	2000	0800	2000		
5/21	1	1	08 SE	24 SE	-	-	3.5	-	0.0	clear
5/22	1	1	11 SE	16 SE	-	-	4.0	-	0.0	clear
5/23	2	1	calm	08 NW	-	13.0	5.0	9.0	0.0	clear
5/24	1	1	calm	24 NE	-	19.0	5.0	10.0	0.0	clear
5/25	2	-	calm	calm	7.0	-	6.0	-	0.0	clear
5/26	3	4	calm	3-08 SE	9.0	11.0	5.5	8.0	0.5	clear
5/27	3	2	8-16 E	16-24 SE	-	12.0	5.0	9.5	-	clear
5/28	2	3	calm	16-24 SE	10.0	-	6.0	9.0	-	clear
5/29	-	1	-	24 SE	-	11.0	-	9.5	1.8	-
5/30	4	1	0-05 SE	16 E	-	10.0	9.5	8.0	-	clear
5/31	2	1	calm	16 NW	-	16.0	7.5	8.0	-	clear
6/01	5	2	0-08 SE	19 E	10.0	8.0	7.5	8.5	-	clear
6/02	1	4	16 SE	32 E	9.5	8.5	5.5	7.0	trace	clear
6/03	1	4	2-05 SE	24 NE	7.0	8.0	5.8	7.0	trace	clear
6/04	3	4	2-08 E	32 E	5.0	7.0	5.0	7.0	2.3	clear
6/05	4	4	16 SE	32 E	8.0	8.5	4.8	6.0	trace	clear
6/06	4/5	4	3-05 SE	05 NNW	12.0	13.0	5.0	7.0	1.8	clear
6/07	4	3	calm	16 WSW	8.0	8.0	6.0	8.5	trace	clear
6/08	4	3	5-11 N	16 W	6.0	10.5	6.2	8.0	trace	clear
6/09	5	3	2-05 SW	calm	0	9.0	5.0	8.5	-	clear
6/10	4	4	3-08 SE	40 SE	12.0	8.5	5.0	5.5	trace	clear
6/11	5	3	2-03 E	19 E	12.5	10.0	4.8	7.5	9.1	clear
6/12	1	-	8-13 SE	-	10.0	-	6.0	-	-	clear

[a] 1 = Cloud cover not more than 1/10
2 = Cloud cover not more than 1/2
3 = Cloud cover more than 1/2
4 = Completely overcast
5 = Fog

[b] Water clarity at 0800 hours

Table 22. Water temperatures at sockeye salmon smolt counting site, Egegik River, 1981-1992.

Year	Sample Period	Water Temperature (°C)			Reference
		Minimum	Maximum	Mean	
1981	May 15 - Jun 08	5.0	9.0	7.3	Bue (1982)
1982	May 15 - Jun 16	0.0	5.0	2.9	Bue (1984)
1983	May 18 - Jun 10	5.0	9.5	7.0	Fried et al. (1987)
1984	May 17 - Jun 11	5.0	10.0	7.6	Fried et al. (1986)
1985	May 17 - Jun 12	2.5	7.5	4.2	Bue (1986c)
1986	May 19 - Jun 12	2.2	7.5	7.2	Bue et al. (1988)
1987	May 18 - Jun 13	3.9	11.0	6.6	Cross et al. (1990)
1988	May 19 - Jun 14	3.0	10.1	6.4	Woolington et al.(1990)
1989	May 21 - Jun 10	3.0	11.0	5.2	Woolington et al.(1991)
1990	May 20 - Jun 11	2.5	10.0	5.4	Crawford et al. (1992)
1991	May 21 - Jun 12	4.0	10.0	6.4	Crawford and Cross (1992)
	Mean	3.3	9.2	6.0	
1992	May 21 - Jun 12	3.5	10.0	6.8	

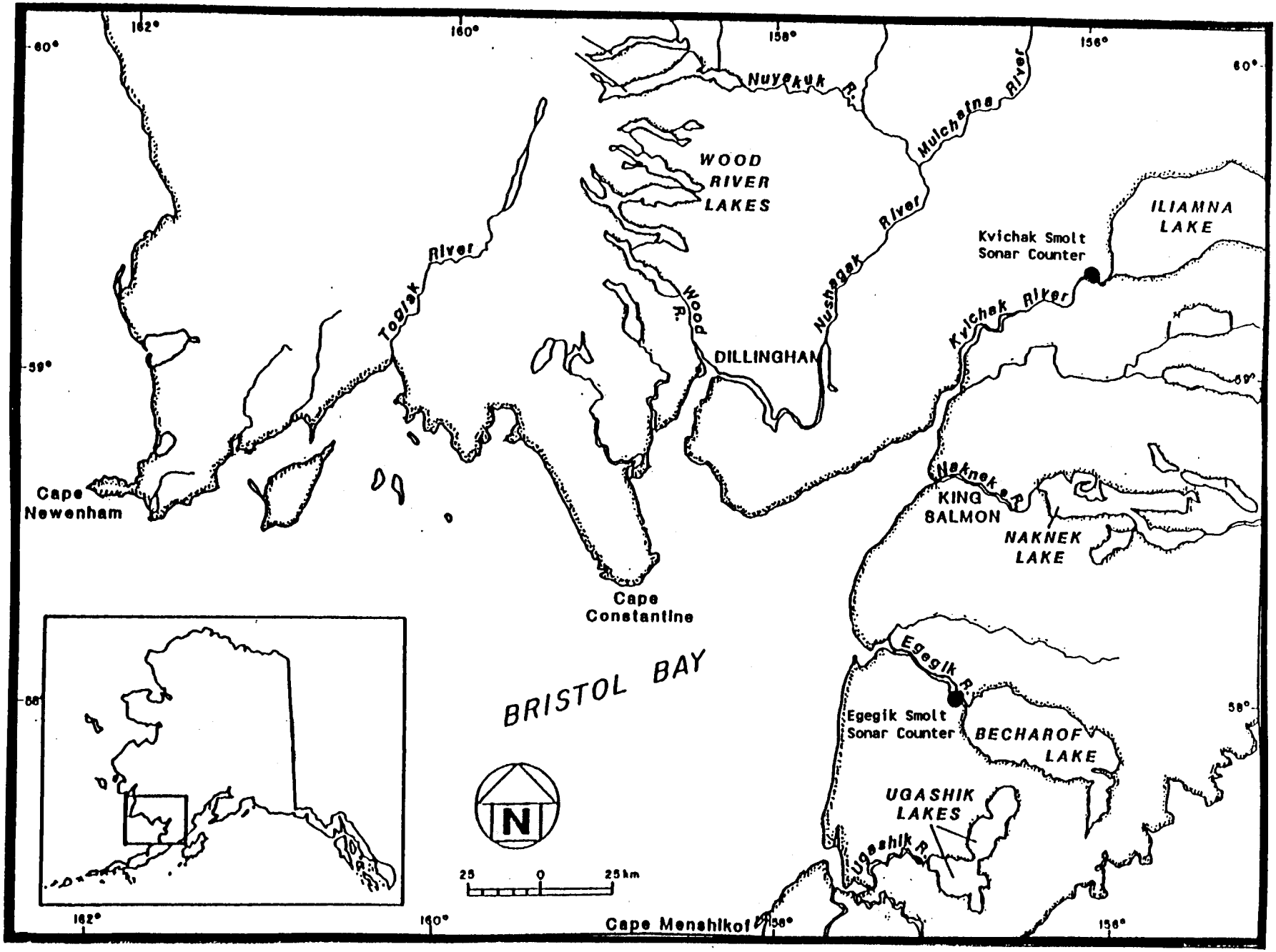

Figure 1. Bristol Bay Management Area with major rivers and locations of smolt counting projects, 1992.

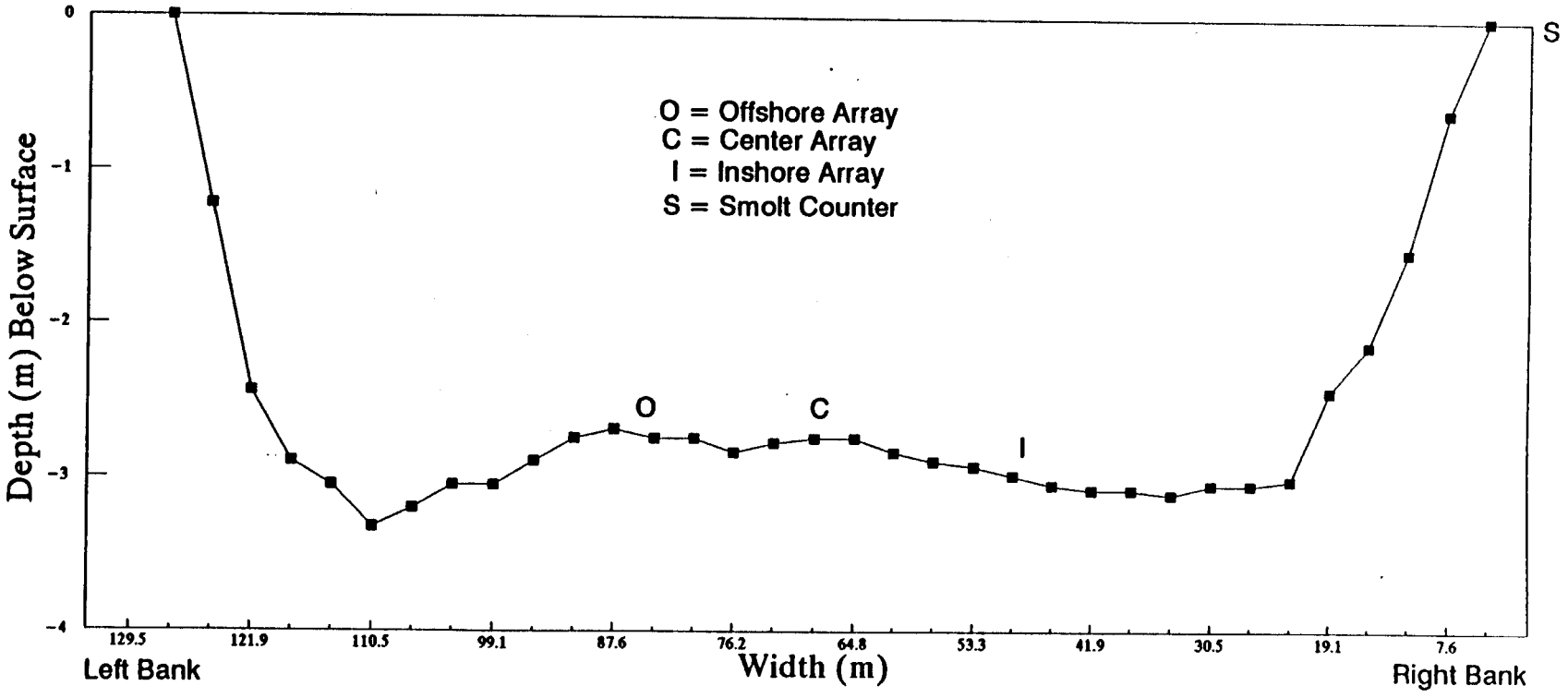

Figure 2. River bottom profile and sonar array placement at Kvichak River smolt site, 1992.

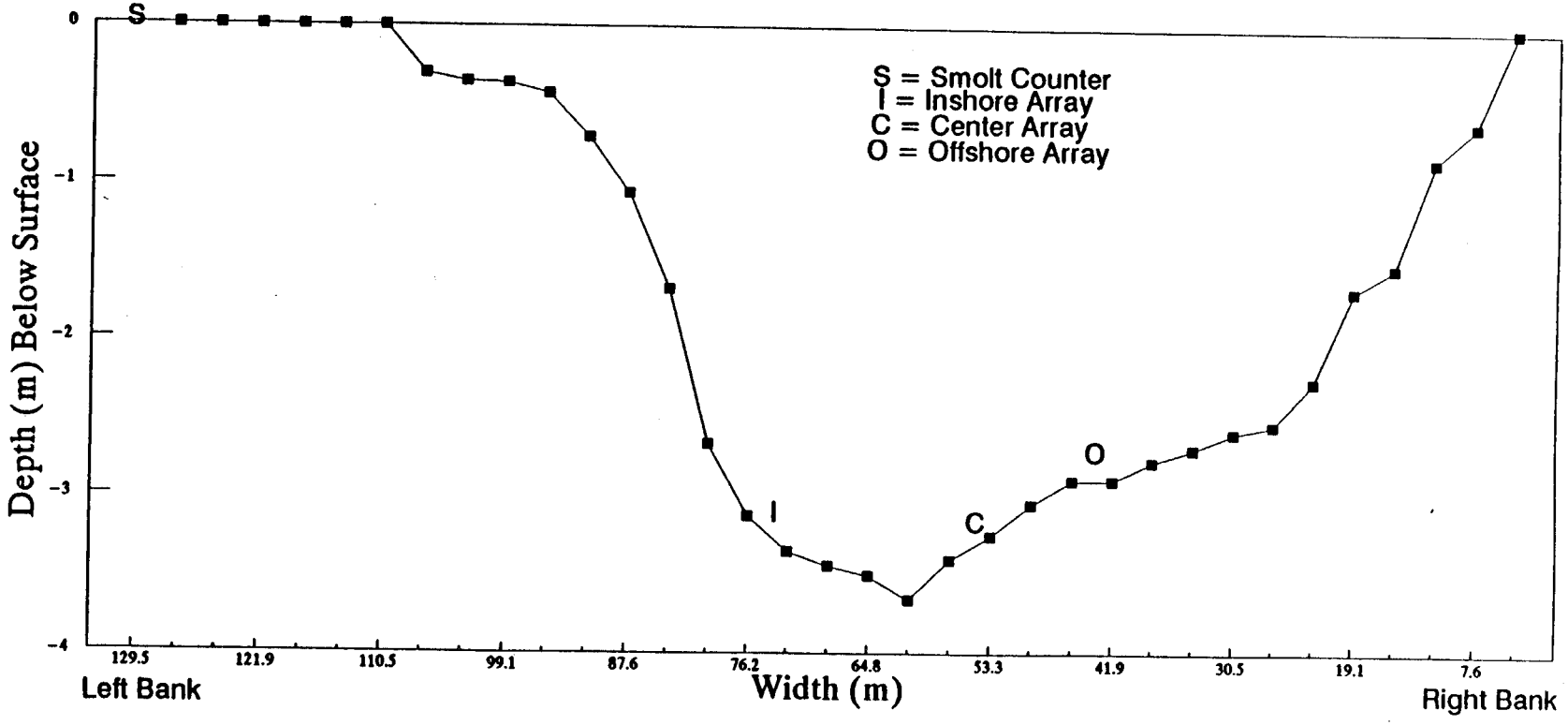

Figure 3. River bottom profile and sonar array placement at Egegik River smolt site, 1992.

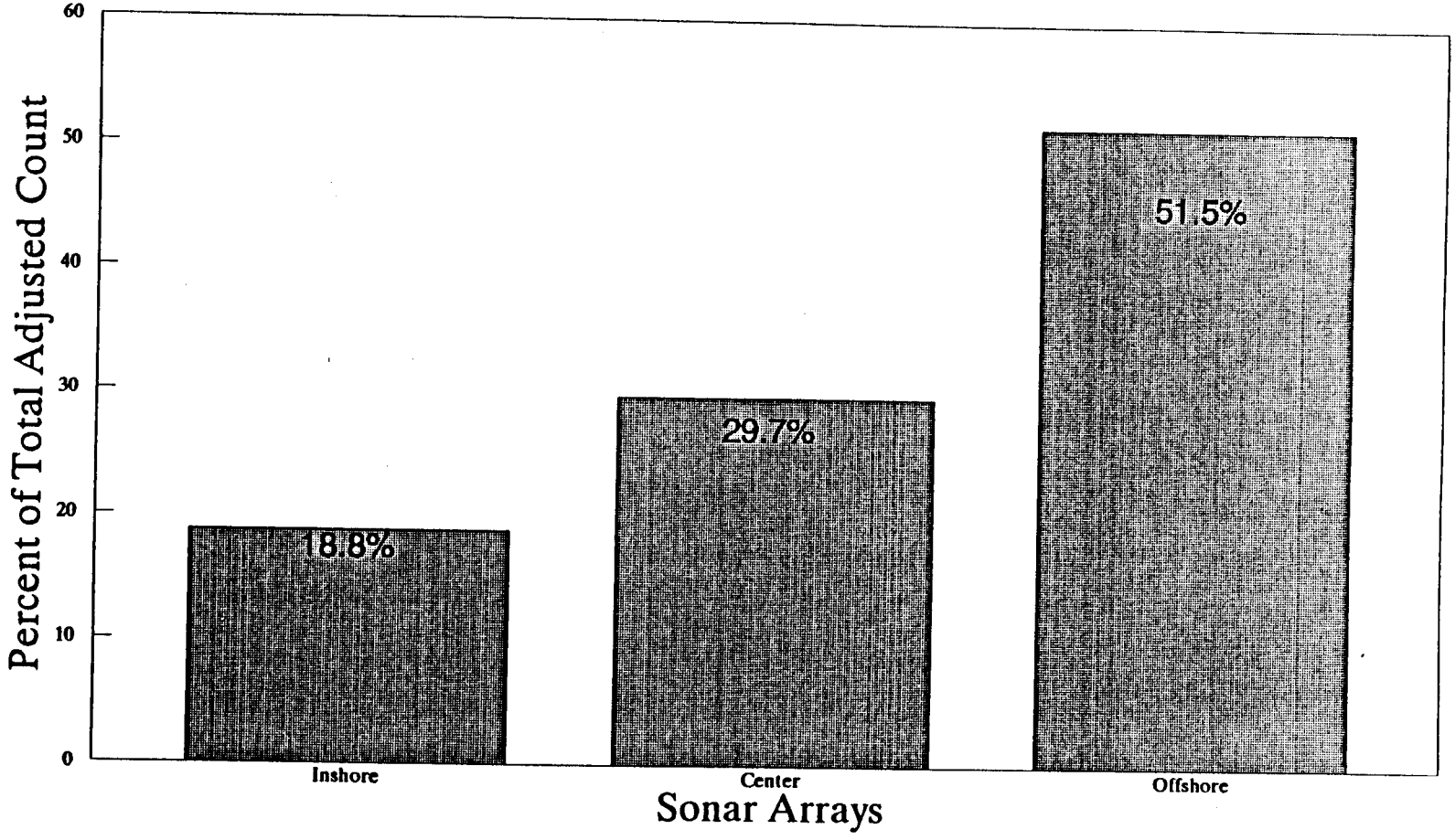

Figure 4. Lateral distribution of Kvichak River smolt sonar counts, 1992.

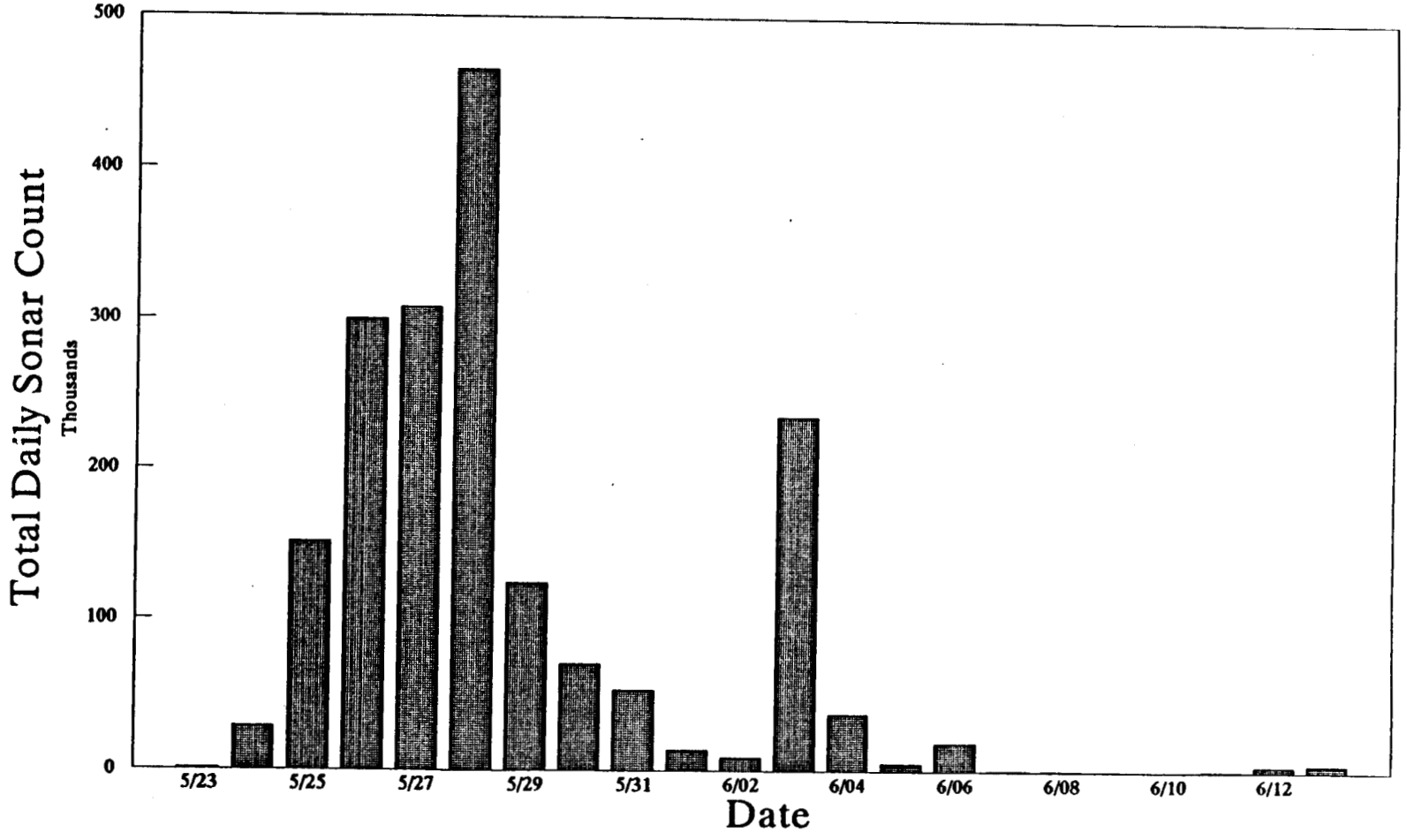

Figure 5. Total daily sonar counts at Kvichak River smolt project, May 23 to June 13, 1992.

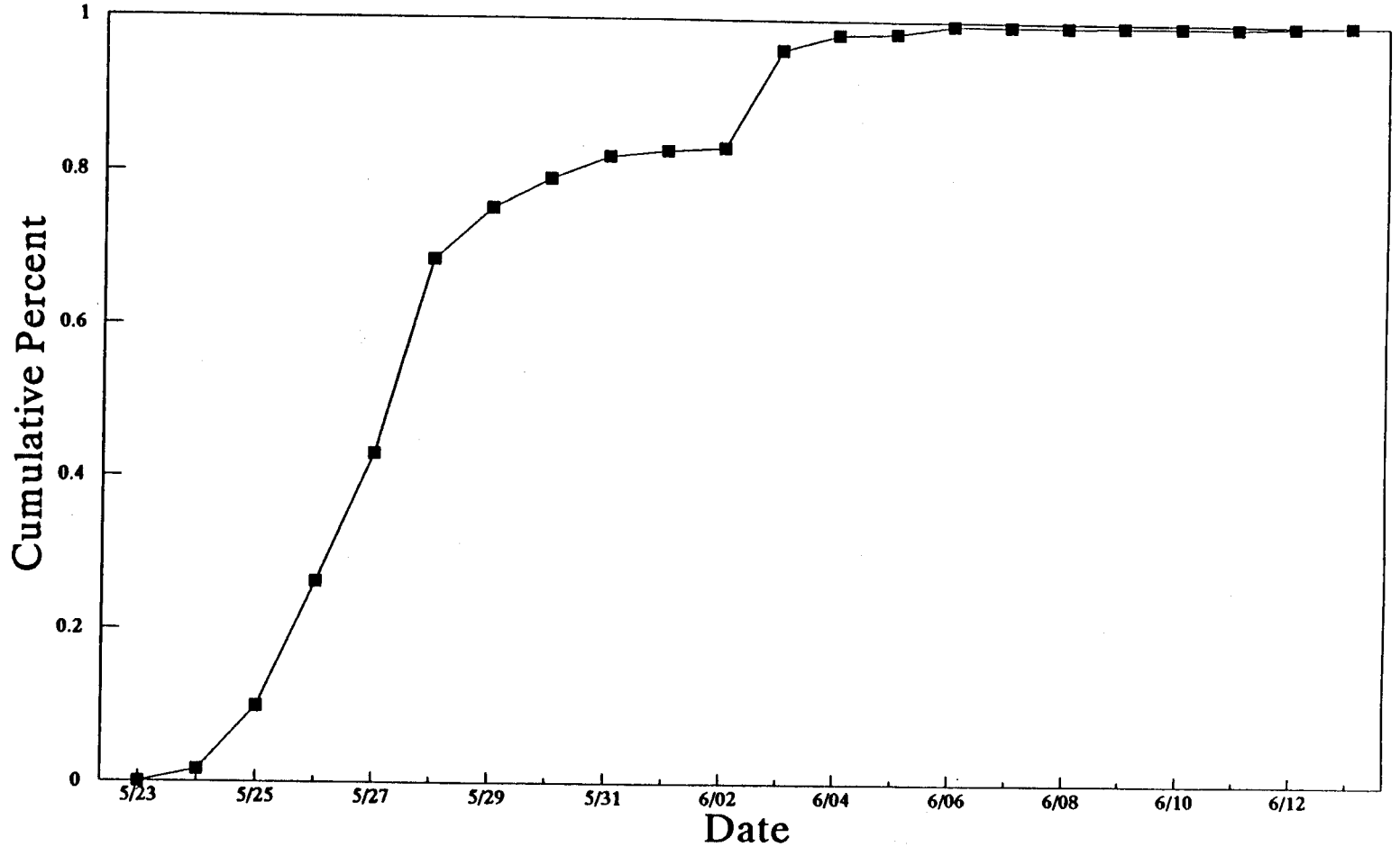

Figure 6. Kvichak River smolt sonar, cumulative percent by date, May 23 to June 13, 1992.

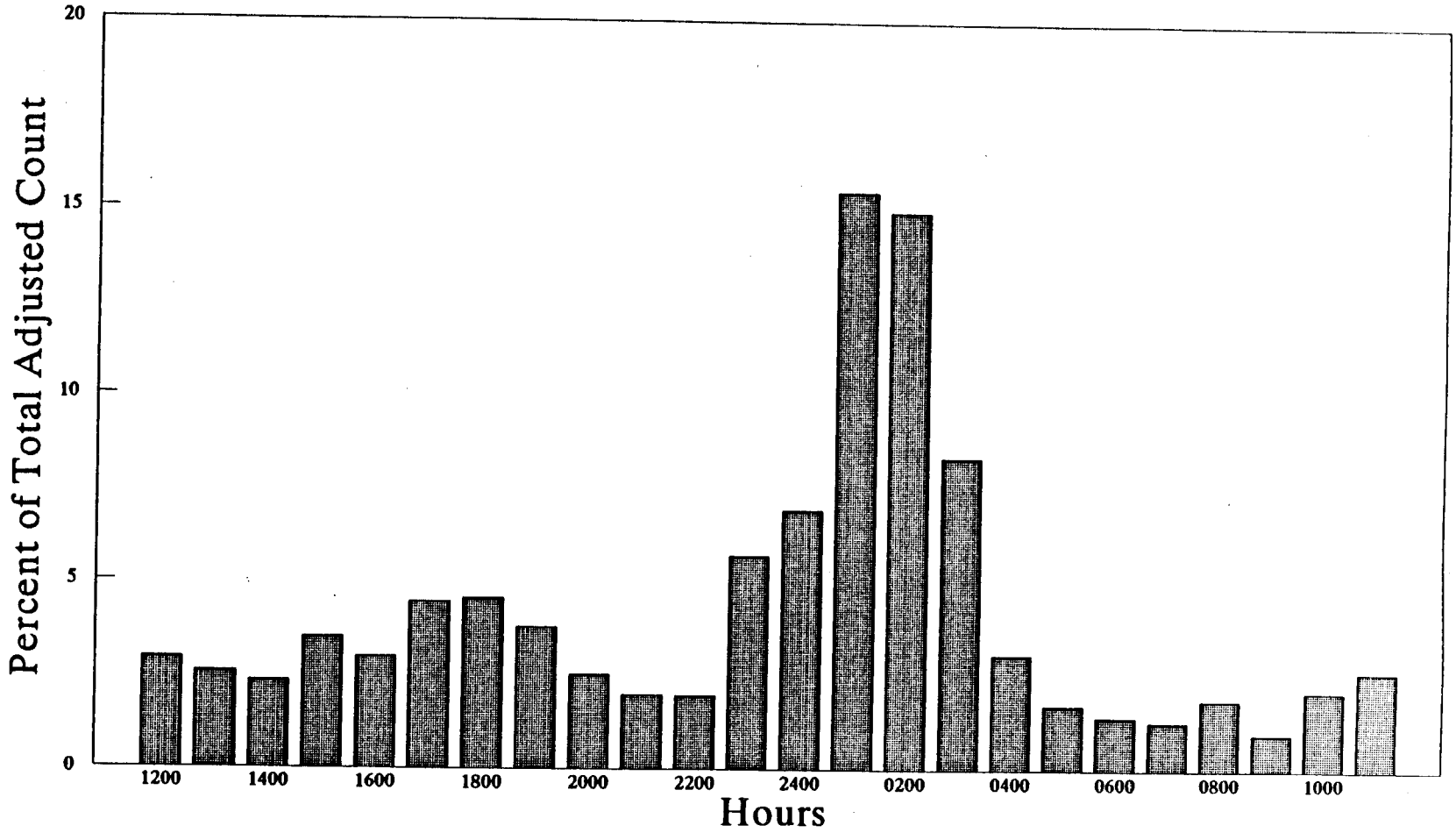

Figure 7. Percent of the total adjusted sonar count summarized by hour, Kvichak River smolt project, May 23 to June 13, 1992.

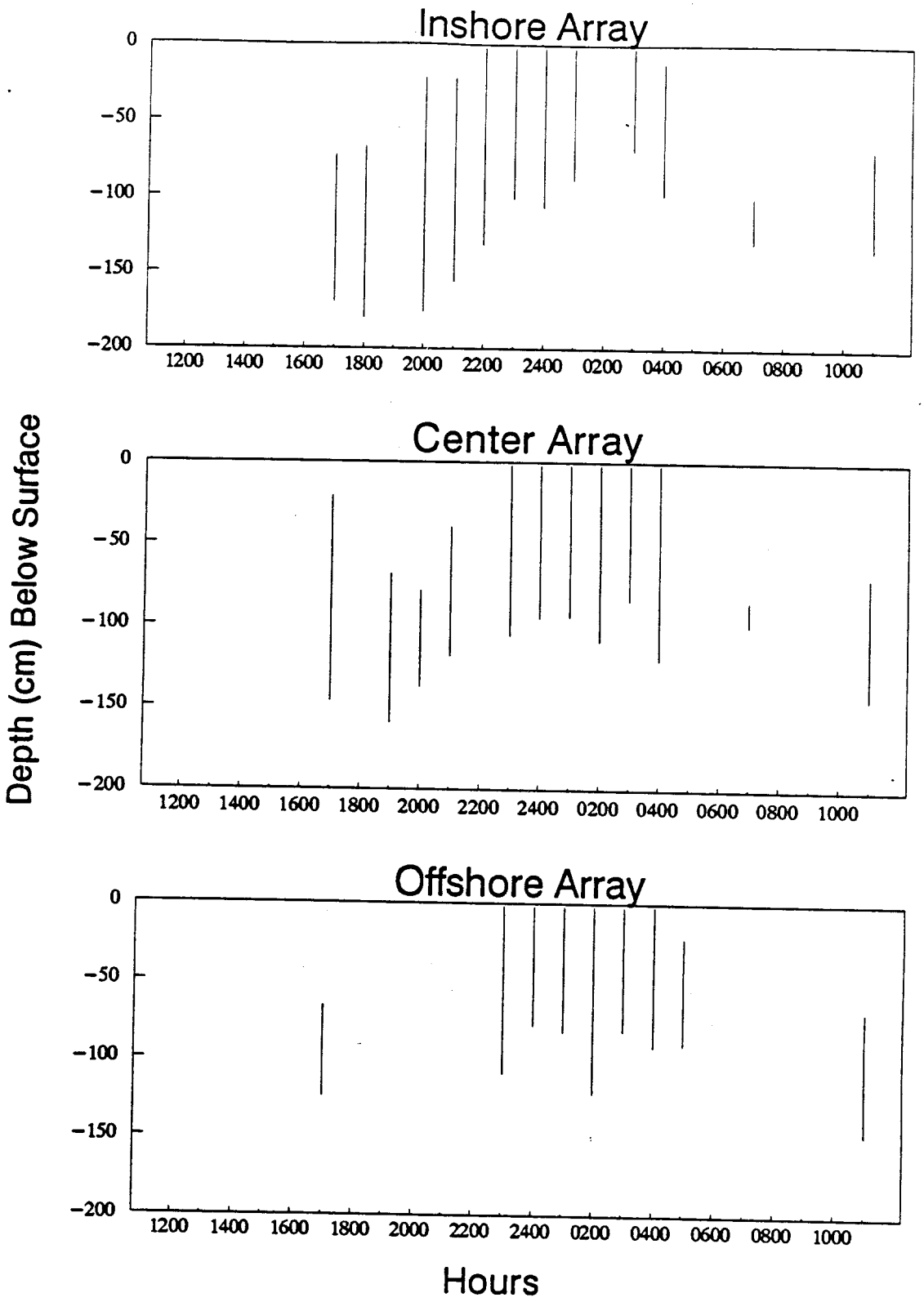

Figure 8. Depth of smolt passage data summarized by hour, Kvichak River, May 23 to June 5, 1992.

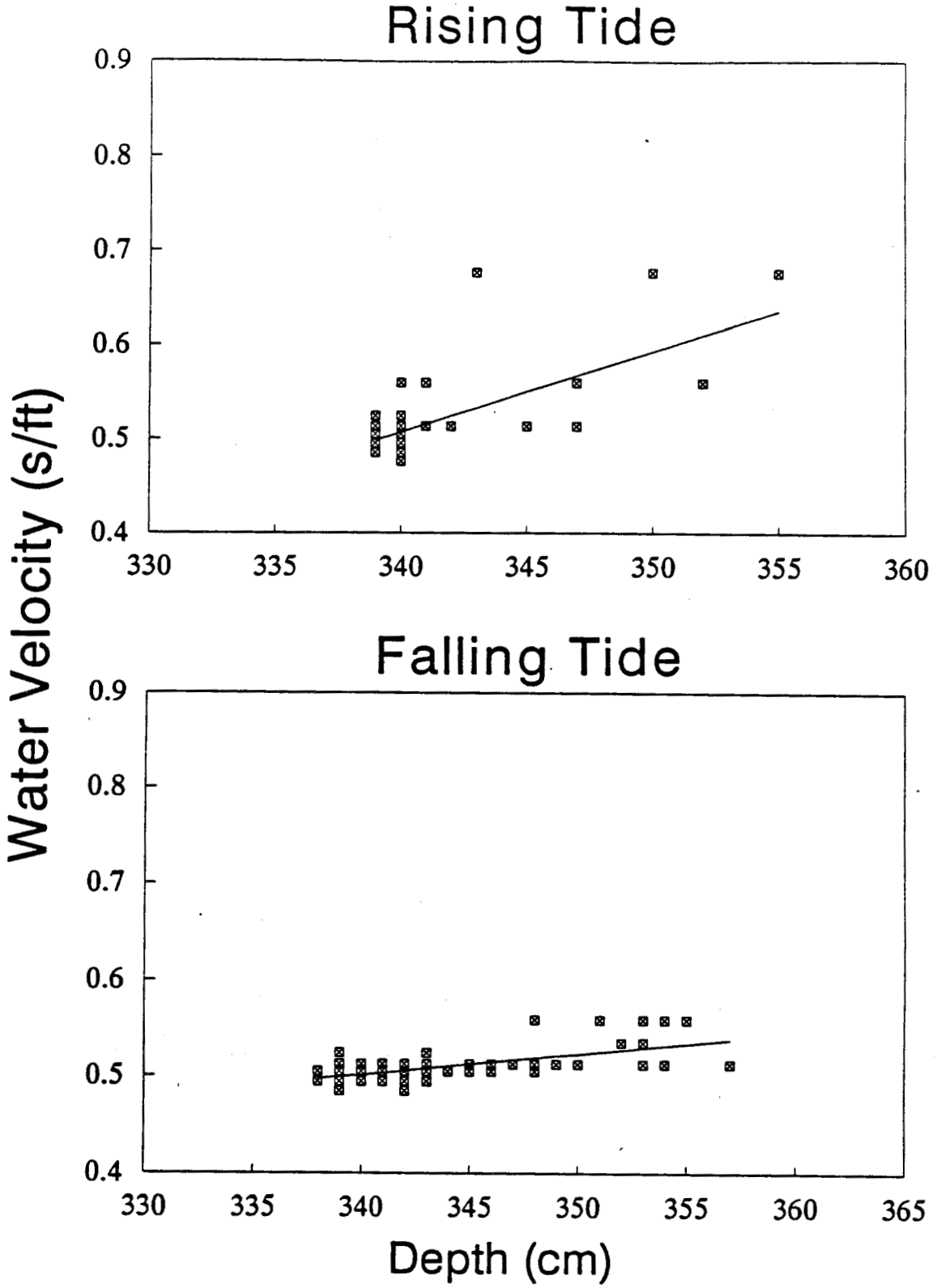

Figure 9. Regression models for the relationships among river depths and velocities for rising and falling tide stages, Egegik River smolt site, June 1 to June 6, 1992.

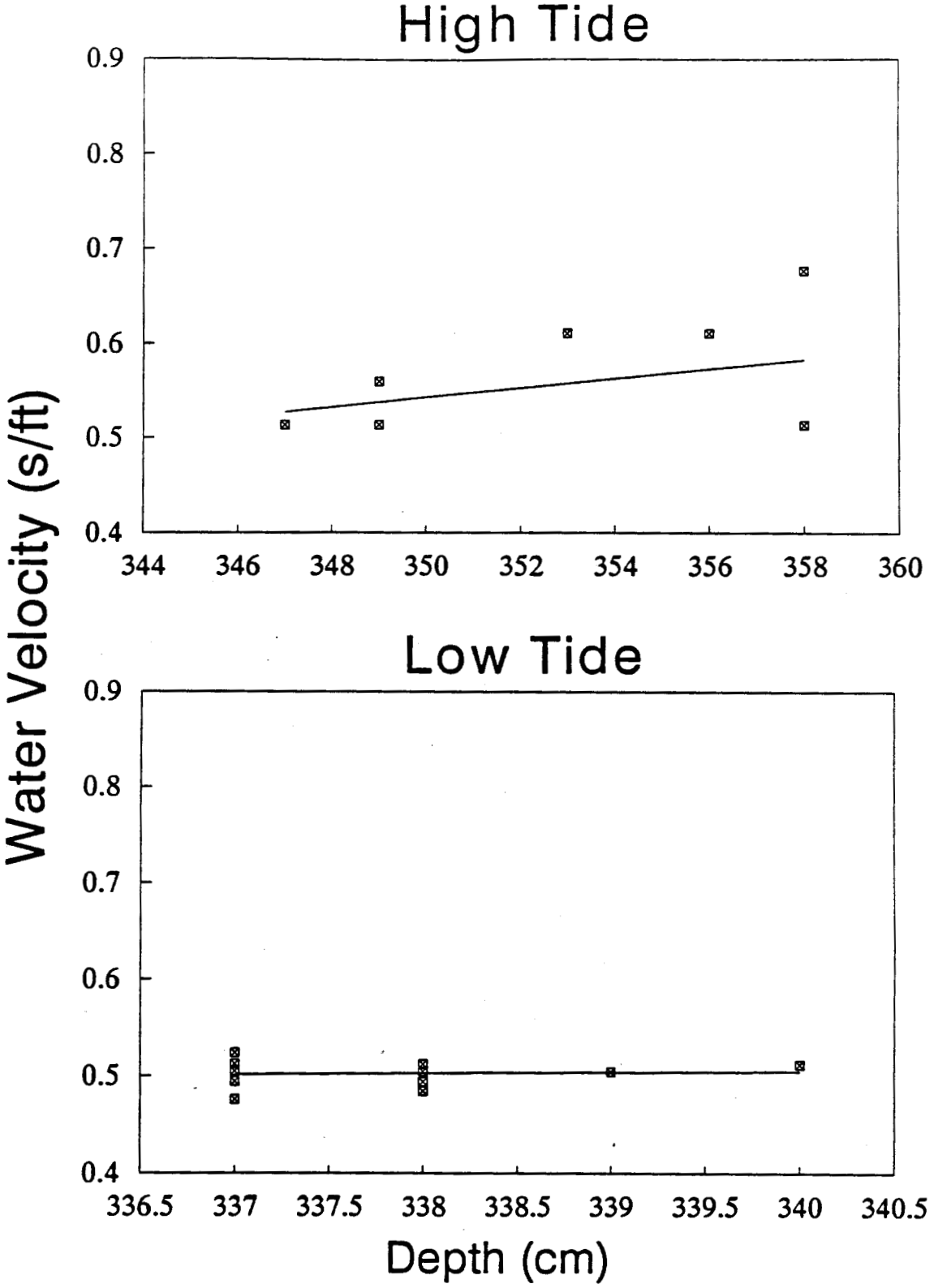

Figure 10. Regression models for the relationships among river depths and velocities for high and low tide stages, Egegik River smolt site, June 1 to June 6, 1992.

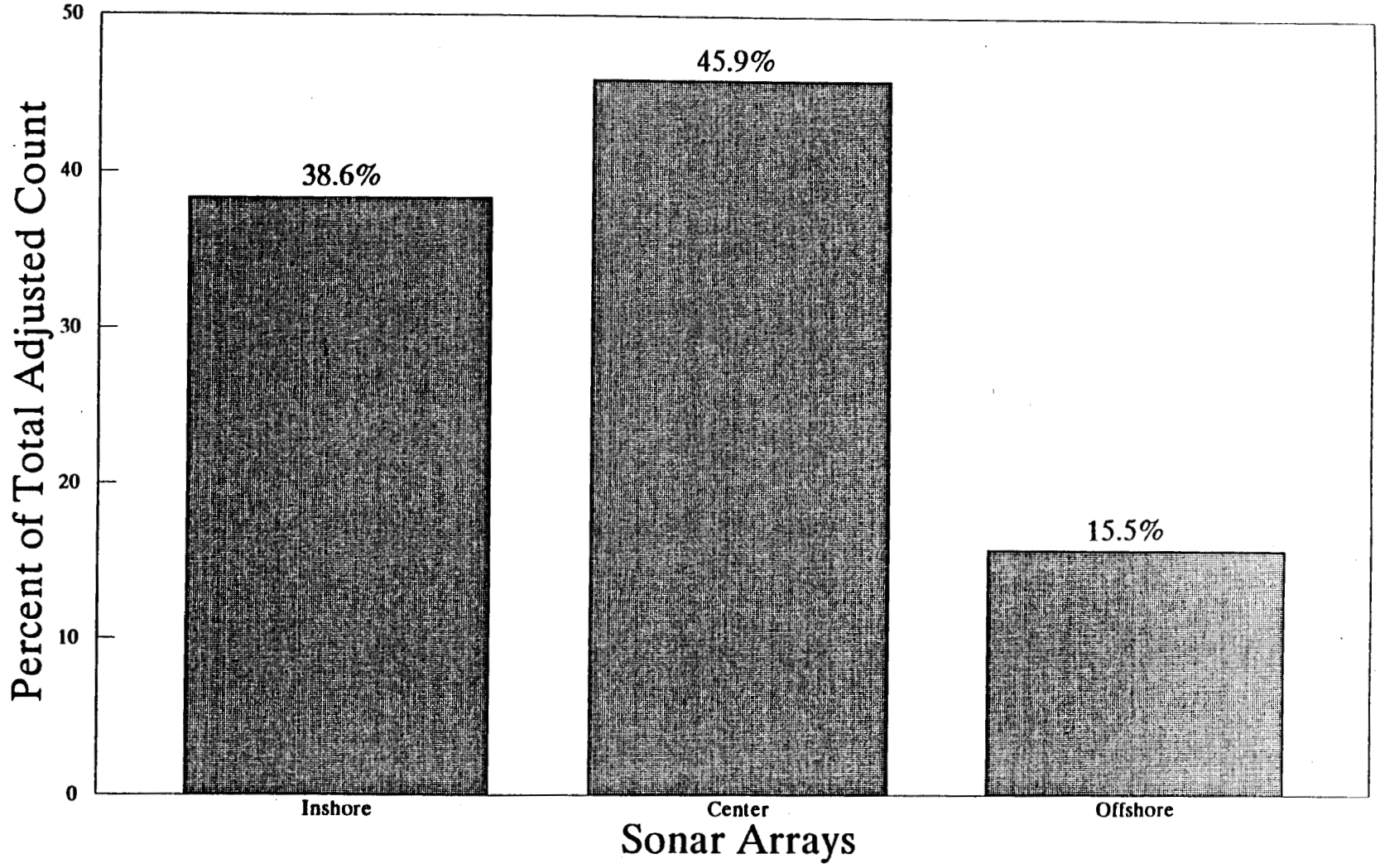

Figure 11. Lateral distribution of Egegik River smolt sonar counts, 1992.

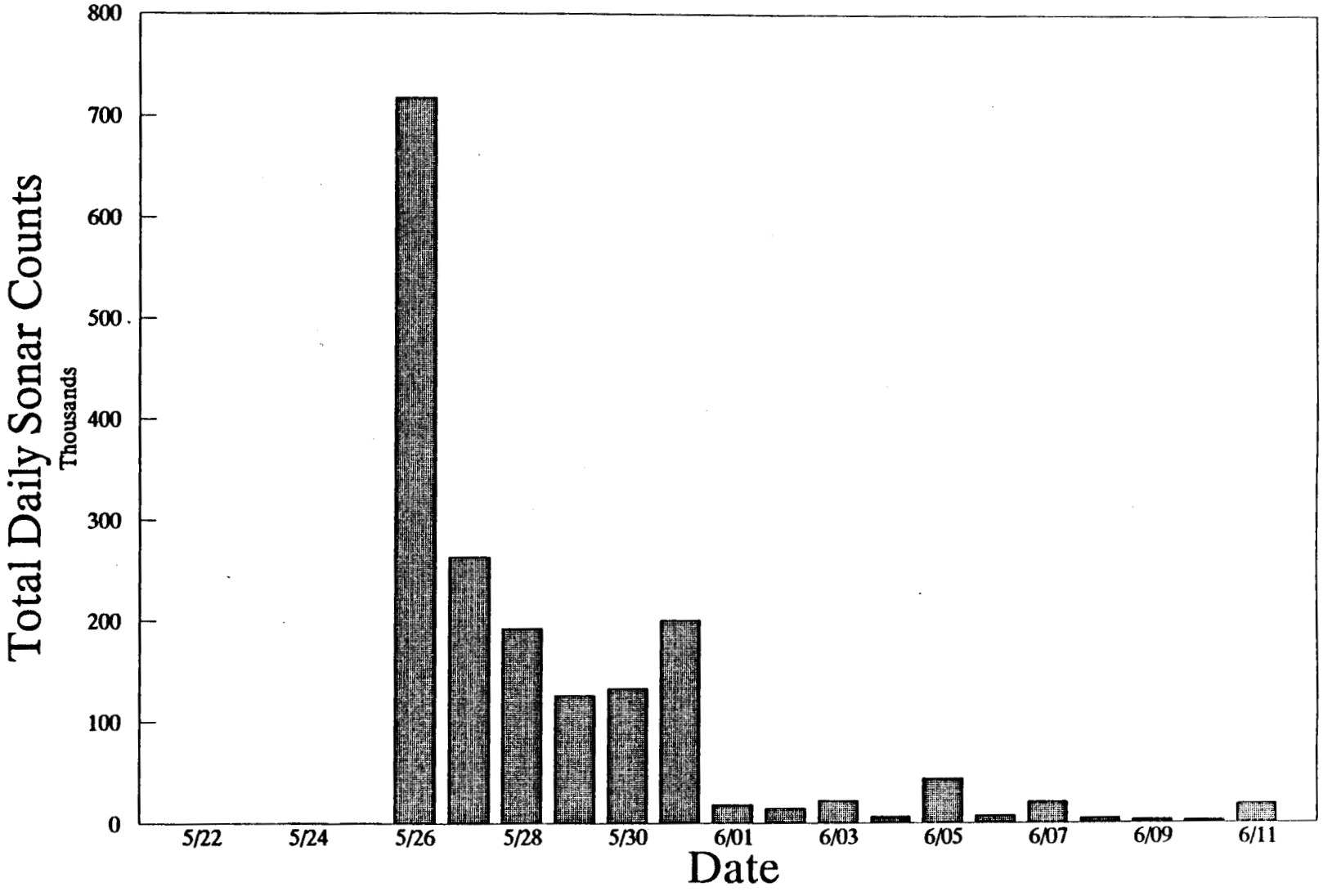

Figure 12. Total daily sonar counts at Egegik River smolt project, May 22 to June 11, 1992.

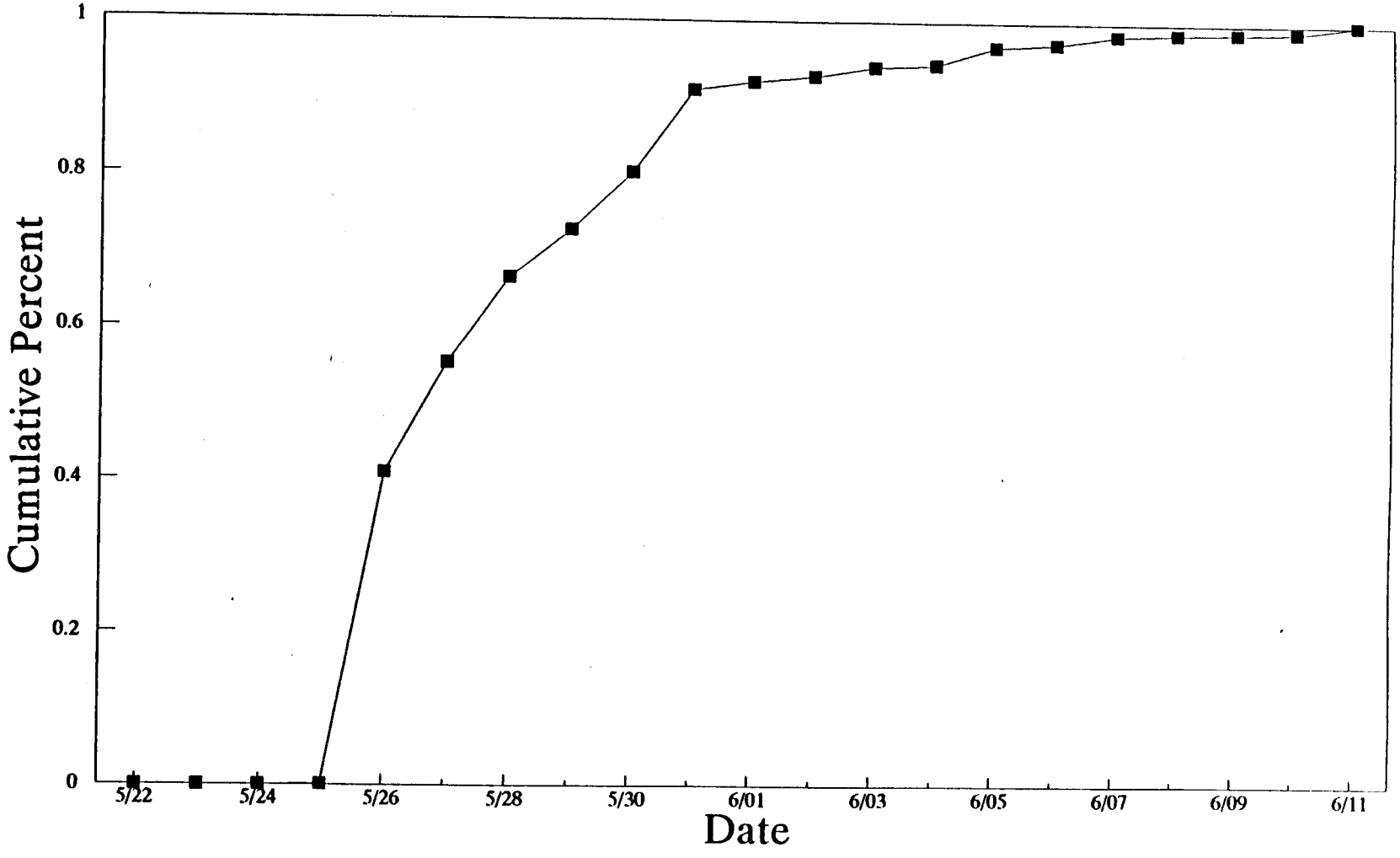

Figure 13. Egegik River smolt sonar count, cumulative percent by date, May 22 to June 11, 1992.

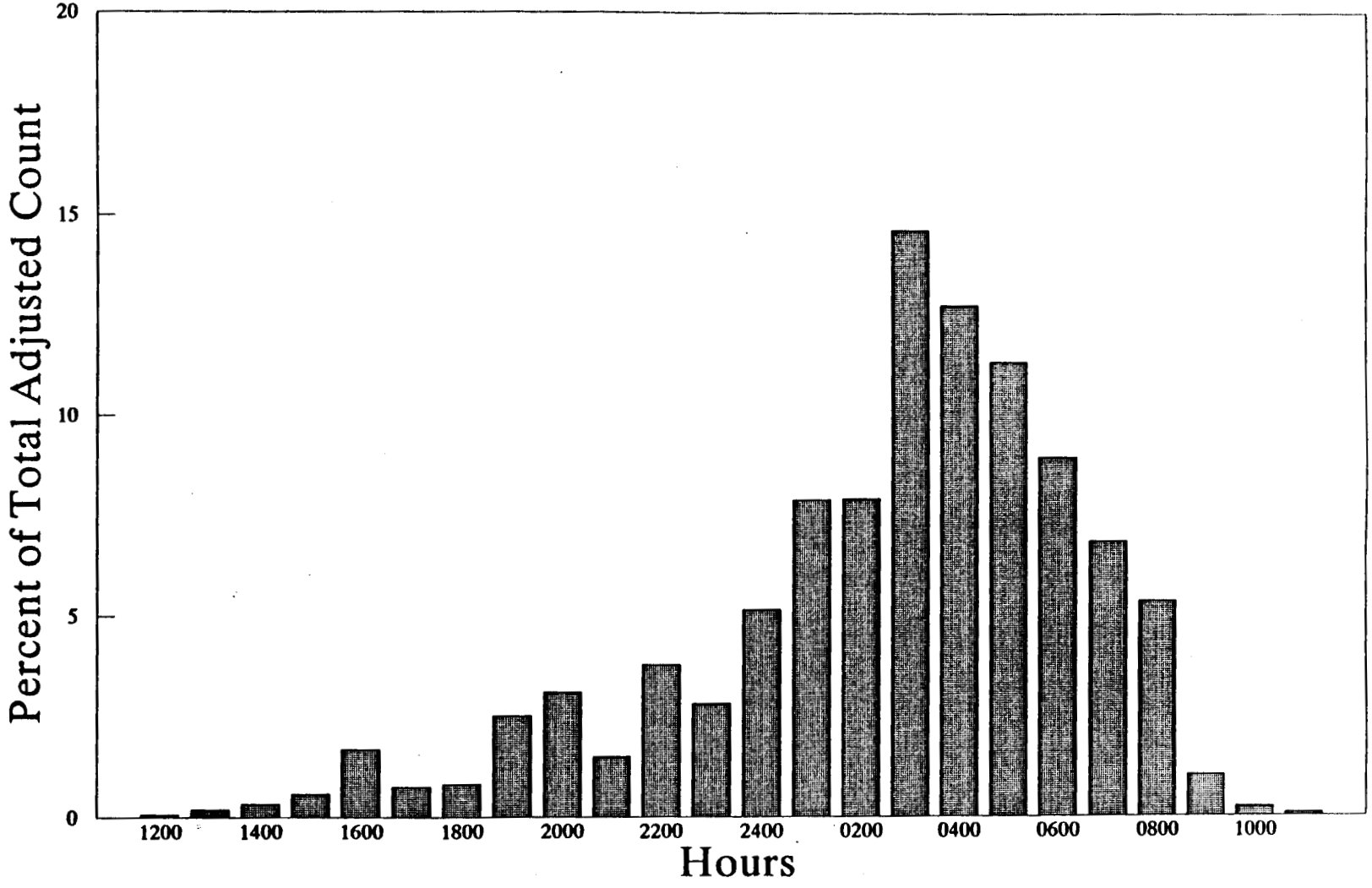

Figure 14. Percent of the total adjusted sonar count summarized by hour, Egegik River smolt project, May 22 to June 11, 1992.

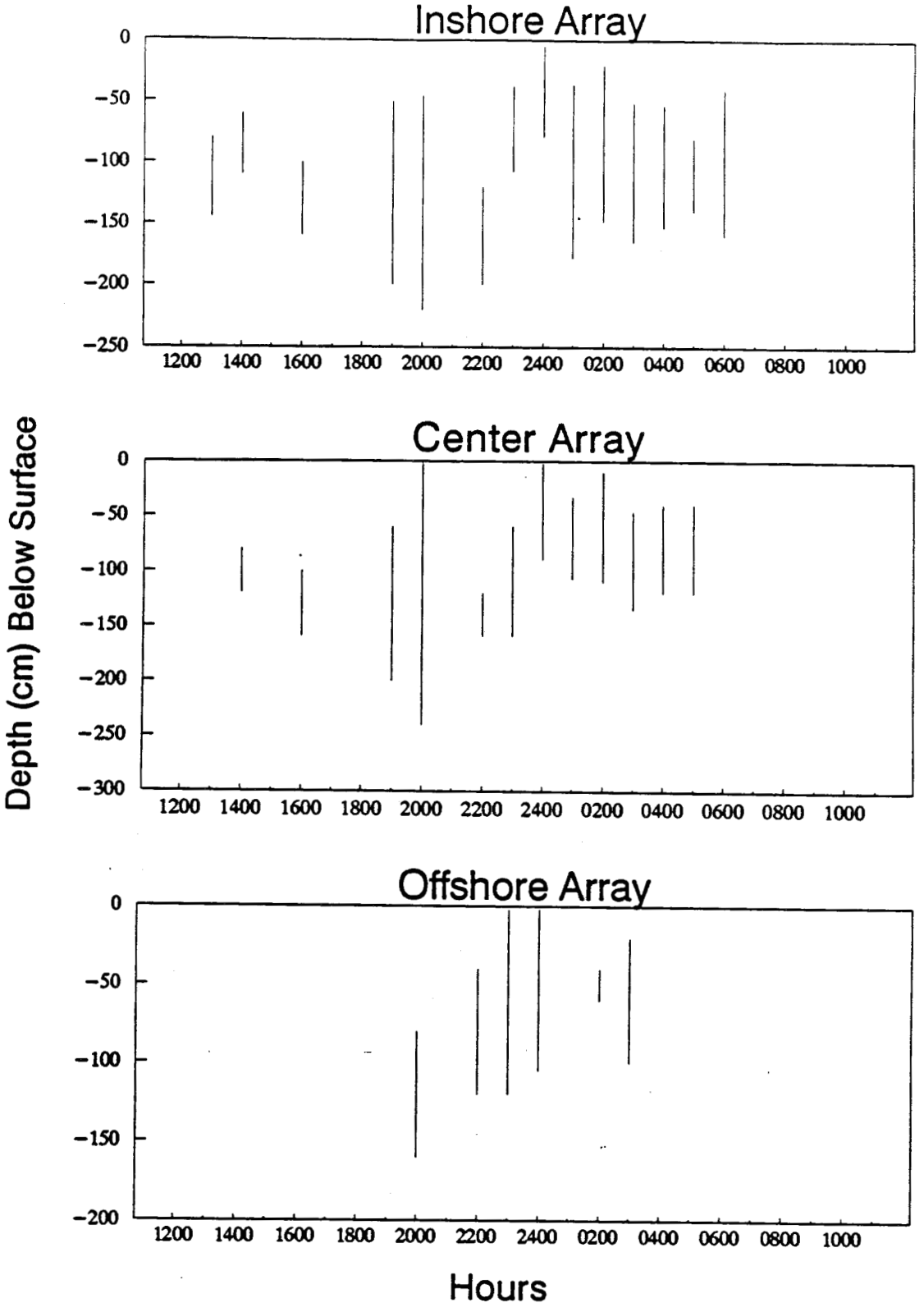

Figure 15. Depth of smolt passage data summarized by hour, Egegik River, May 26 to June 11, 1992.